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SOME SYSTEMATIC MODEL EXPERIMENTS OF THE BOW-SPRAY CHARACTERISTICS OF FLYING-BOAT HULLS OPERATING AT LOW SPEEDS IN WAVES

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NACA
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[redacted] REPORT

SOME SYSTEMATIC MODEL EXPERIMENTS OF THE BOW-SPRAY CHARACTERISTICS OF FLYING-BOAT HULLS OPERATING AT LOW SPEEDS IN WAVES*

By F. W. S. Locke, Jr.

SUMMARY

Tests were run in the Experimental Towing Tank at the Stevens Institute of Technology on models of two flying boats, the XPB2M-1 and the XPBB-1, on a model of a flying boat that at present is in the design stage, the "JRM-1," and on 11 other models derived from the XPB2M-1 to determine the effect of bow form on the amount of spray thrown onto the windshield of a flying boat in rough water at low taxying speeds. The variables studied include the effect of length-beam ratio, the effect of hull dead rise, the effect of forebody warping, the effect of changes of the bow alone, and the effect of afterbody angle.

The results obtained from tests of these models indicated that the height and the volume of spray at the windshield can be reduced by (1) increasing the hull length and especially the forebody length, (2) increasing the "sharpness" of the bow lines below the chine, (3) increasing the static trim when the bow form is such that relatively bad spray otherwise occurs, and (4) decreasing the water-borne load. These changes are listed approximately in the order of their importance from the point of view of reducing spray.

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*A complete report on this investigation entitled "The Bow-Spray Characteristics of Flying-Boat Hulls at Low Speeds in Waves Encountered Head-on," by F. W. S. Locke, Jr., is available for reference or loan in the Office of Aeronautical Intelligence, National Advisory Committee for Aeronautics, Washington, D. C. This report includes a detailed description of the test method and the procedure and numerous photographic studies of the bow spray of the various models tested.

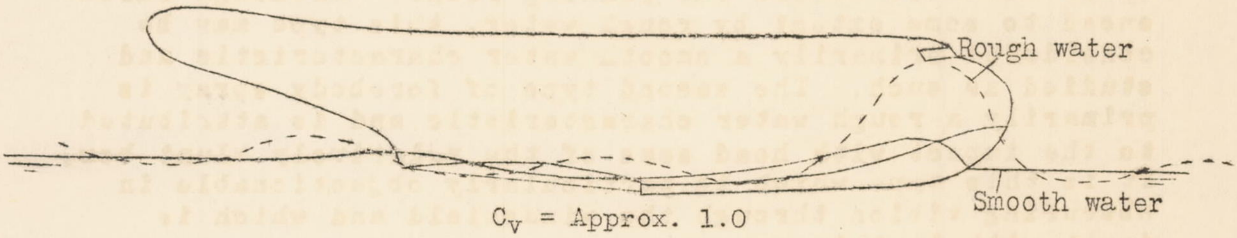
The general conclusion appears to be warranted that any change in hull form which softens the impact between hull and waves tends to reduce the spray thrown onto the windshield at low speeds.

INTRODUCTION

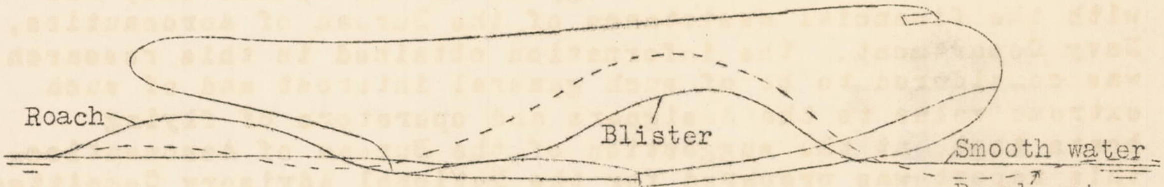
War conditions have accentuated the need for flying boats which are able to operate in reasonably heavy weather with a maximum of safety. At the same time, the decreasing average of pilot experience has focused attention on the need for ease of operation. In the past there has been less emphasis on the seagoing qualities of flying boats than on other characteristics.

One of the problems met with in rough water is that spray thrown up by the bow of the hull at low taxying speeds may strike the windshield and obscure the pilot's vision for an appreciable time during the take-off run. Undesirable bow spray has also been encountered even in smooth water operation of some flying boats operating in an "overload" condition. Besides obscuring the pilot's vision temporarily, the spray may also leave a salt deposit on the windshield which tends to obscure vision for the whole flight. This is always unpleasant and may be highly dangerous.

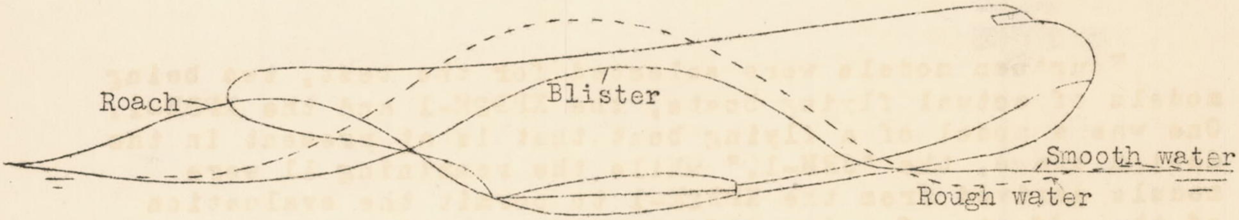
The forebody of a flying-boat hull causes at least two more or less distinct types of spray (reference 1). These are indicated in the following sketches:



C_V = Approx. 1.0



C_V = Approx. 1.7



C_V = Approx. 2.5

Hump occurs at C_V = Approx. 2.8

The first type grows out of the bow wave at very low speeds and builds up in the form of a blister of increasing height with the peak progressively farther aft as the speed advances toward the planing range. Although influenced to some extent by rough water, this type may be considered primarily a smooth water characteristic and studied as such. The second type of forebody spray is primarily a rough water characteristic and is attributed to the impact with head seas of the relatively blunt bow. It is this type which is particularly objectionable in obscuring vision through the windshield and which is dealt with in this report.

In order to ascertain the causes of adverse bow-spray characteristics, an investigation was conducted at the Stevens Institute of Technology under the sponsorship and with the financial assistance of the Bureau of Aeronautics, Navy Department. The information obtained in this research was considered to be of such general interest and of such extreme value to the designers and operators of flying boats that, at the suggestion of the Bureau of Aeronautics, this report was prepared for the National Advisory Committee for Aeronautics in order that the more important results could be made readily available to interested parties.

DESCRIPTION OF MODELS

Fourteen models were selected for the test, two being models of actual flying boats, the XPB2M-1 and the XPBB-1. One was a model of a flying boat that is at present in the design stage, the "JRM-1," while the remaining 11 were models derived from the XPB2M-1 to permit the evaluation of the effects of quite different bow sections on the bow-spray-characteristics. The variables studied included a comparison of actual or proposed flying boats, the effect of length-beam ratio, the effect of hull dead rise, the effect of forebody warping, the effect of changes of the bow alone,and the effect of afterbody angle. The following tabulation gives the designation of the various groups, the variables studied, and the model designation:

Group	Description	Significant parameter	Model designation
A	Actual or proposed flying boats	XPB2M-1 XPBB-1 "JRM-1"	339-1 441-1 417-29
B	Altered length-beam ratio	L/B = 5.07 L/B = 6.19 L/B = 7.32 L/B = 8.45	339-22 339-1 339-23 339-46
C	Altered hull dead rise	10° dead rise 20° dead rise 30° dead rise	400-1 339-1 401-1
D	Altered forebody warping	1.7°/b warping 5.4°/b warping 10.8°/b warping	339-1 339-39 339-41
E	Altered bow sections	"Fuller" Normal "Finer"	339-18 339-1 339-47
F	Altered afterbody angle	5° afterbody angle 7° afterbody angle 9° afterbody angle	339-29 339-1 339-48

The models in groups A, B, and C used their own afterbodies. The models in groups D, E, and F used the afterbody of the XPB2M-1. A complete list of the particulars of all the models is given in table 1. Body plans and profile drawings of the bows are given in figures 2, 4, 6, 8, 10, 12, and 14. Figures 1, 3, 5, 7, 9, 11, and 13 present the static properties of the hulls under consideration.

For all models the center of gravity was located at 35 percent of the beam forward of the step and 90 percent of the beam above the keel. This position was selected in consideration of trim requirements in the planing range. It is in accordance with the findings of reference 2 in this respect, besides being a fair average position as found in actual flying boats.

The forward part of each forebody was a complete representation of the hull - that is, the turret and windshield were reproduced. The actual designs for these parts were used for the models of group A. For the models of groups B, C, D, and E an arbitrary design was used in which the windshield was located at the same distance above the base line and at the same distance aft of the forepoint in all cases. The models in group F used the forebody of the XPB2M-1.

Group A - Actual or Proposed Flying Boats

The XPB2M-1 was included because, in addition to its being a convenient parent, available flight experience with the actual flying boat indicated that there was occasional difficulty with the spray being thrown up onto the bow. The "JRM-1" model is one of several developed for the JRM-1. It has desirable resistance, porpoising, and yawing characteristics and represents a considerable effort toward developing satisfactory bow lines for rough water at low speed. The XPBB-1 was selected because it has an unusual bow and because it was reported to be quite satisfactory in waves at taxying speeds. The static properties and the lines of these hulls are shown in figures 1 and 2 and a photograph of the group is shown in figure 15. The lines of the XPB2M-1 are shown in figures 4 and 14.

Group B - Length-Beam Ratio

The hull length was altered by applying a constant multiplier to the station spacing of the XPB2M-1 parent. On the afterbody the stations were moved in or out along the afterbody keel and on the forebody along lines parallel with the tangent to the forebody keel at the main step. Four values of the length-beam ratio were investigated. With the beam held constant, the hull length was altered according to the following values of hull-length-beam ratios: 5:07, 6.19 (the normal value for the XPB2M-1), 7.32, and 8.45. Increasing the length reduced, the curvature of the buttocks on the forebody. The step height and the afterbody keel angle were unaltered. The static properties and lines of these models are shown in figures 3, 4, 5, and 6 and a photograph of the group is shown in figure 17.

Group C - Hull Dead Rise

The hull dead rise was altered by multiplying the dead rise of each station by the same constant. Three hulls were included in this group with dead rise angles of 10°, 20°, and 30°, respectively, at the step. The keel profile was unaltered but the chines were changed as necessary. The chine flare was increased or decreased in proportion to the dead rise. The static properties and the hull lines of this series of models are shown in figures 7 and 8; a photograph of the group is shown in figure 16.

Group D - Forebody Warping

The forebody bottom was warped by leaving the section at the main step unchanged and varying the dead rise linearly from the step to the forepoint. The profile and the chine plan form were unaltered. The use of linear dead rise variations throughout the whole length of the forebody produced rather flat bow sections. The deviation from the parent model (XPB2M-1) was obtained by varying the dead rise linearly from the step in the ratios of 10.8°/b length and 5.4°/b length. The static properties and the hull lines of this series are shown in figures 9 and 10; figure 18 is a photograph of the models.

Group E - Bow Sections

The first forebody in this group, Model No. 339-18, referred to as "fuller" had the length of the normal forebody but all the sections of the normal forebody were compressed into the forehalf, making the bow very blunt. The after half of this forebody had the uniform section of the main step in the parent hull. The second forebody of this group, Model No. 339-47, was an attempt to improve the XPB2M-1 by a small change to the forward part of the forebody which made the bow somewhat "finer." The chine was raised and the dead rise increased from the forepoint to about half a beam after the forepoint. The static properties and the hull lines are shown in figures 11 and 12, and a photograph of the group is shown in figure 19.

Group F - Afterbody Angle

One of the conditions suggested for tests was that the static flotation be changed. The simplest way to do this is to shift the center of gravity longitudinally. However, because in practice the center of gravity cannot be shifted materially without disturbing trim control in the planing range, it was decided that the best way to change the static flotation was to alter the afterbody angle. This was accomplished by rotating the afterbody at the intersection of its keel with the main step, leaving the step height unchanged. The changes of angle would, of course, alter other characteristics such as hump resistance but would not seriously interfere with trim control on the planing range. Three values of afterbody angle were tested, 5°, 7°(normal for the XPB2M-1), and 9°. The static properties and the hull lines of this series are shown in figures 13 and 14.

APPARATUS AND TEST PROCEDURE

The model was mounted on an apparatus which allowed freedom in pitch and heave and provided restraint in roll and yaw. A complete description of this apparatus is given in reference 1. A calibrated paddle, part of the regular equipment of the Experimental Towing Tank at Stevens, was used to make the waves, and the spray was photographed with special equipment.

For making the photographic studies a 35-millimeter moving picture camera was used in connection with a multiple flash lamp developed by Dr. Harold E. Edgerton of the Massachusetts Institute of Technology and loaned to Stevens Institute of Technology for the purpose of these experiments. The light worked on ordinary alternating current and flashed 60 times a second. The period of each flash was about 0.00005 second. Film was sent through the camera at constant speed with the shutter removed. The exceedingly short flash time of the lamp insured stopping the motion of all spray particles even with moving film. The camera and light were mounted on an auxiliary carriage which moved with the model.

The paddle used for making waves was specially calibrated before the inception of the tests. The waves generated by this paddle were smoother than those usually encountered in a seaway, corresponding quite closely to the conventional theoretical trochoid. The waves used never took the shape of "cusps" which are usually found in bays and harbors in combination with a stiff breeze.

While it is in the latter type of wave that flying boats often have to operate, it was considered more important to use waves which could be reproduced easily and accurately so that tests of different models could be made under controlled test conditions. The smooth and regular waves used in the test are frequently found in practice, however, so that it is perfectly proper to use them. No attempt was made to reproduce the wind that might be expected to accompany the various wave sizes.

Very extensive tests were run on one model, Model No. 339-29, which was thought at the start to have a poor bow from the standpoint of low-speed bow spray, in order to decide upon the most suitable speeds and wave conditions for the tests of the entire series. It was found that the spray was more sensitive to the speed of the model than to the wave size and that the influence of the wave slope was relatively unimportant The tests also indicated that moderate pitching did not necessarily influence spray height.

It was concluded on the basis of these exploratory tests that one speed corresponding to $C_V = 1.05$ (approx. 15 mph full-scale speed for the XPB2M-1) was sufficient to get a critical view of the behavior of the whole series of models in rough water. Three loads corresponding to $C_\Delta = 0.6$, 0.8, and 1.0 were chosen as representing the range of loading of practical interest. Inasmuch as the effect of wave slope had been shown to be negligible, all tests were conducted with waves having a length-height ratio of 20. This ratio is considered to be reasonably representative of the waves actually encountered in practice. Tests were run with each of three heights of wave equal to 0.1, 0.2, and 0.3 of the beam of the model. These heights were chosen to bracket the limited reports of full-scale experiments which were available when the work was undertaken.

The tests of the models which involved changes of over-all hull length were carried to considerably higher values of C_Δ to determine the maximum practical loading in terms of length.

In recording the results of each test sufficient film was taken to get two or three complete cycles of the model encountering a wave. Analysis of the film showed that, in general, the behavior of the model in successive cycles of one train of waves was remarkably constant.

From each film one frame was selected which showed the spray at the worst point in the cycle. The selection of this one frame was by no means critical and any frame within two or three on either side of the selected frame could have been chosen without materially affecting the results.

RESULTS AND DISCUSSION

Presentation of Data

Nondimensional coefficients based on Froude's law were used to present the results of the tests. The nondimensional coefficients and ratios used throughout this report are defined as follows:

C_Δ	load coefficient (Δ/wb^3)
C_M	trimming-moment coefficient (M/wb^4)
C_V	speed coefficient $(V/\sqrt{gb})$
C_d	draft coefficient (d/b)
L/B	length-beam ratio
L/H	wave length-height ratio
Δ	load on water, pounds
b	beam at step, feet (used interchangeably with B)
w	specific weight of water, pounds per cubic foot (62.3 for these tests usually taken as 64.0 for sea water)
M	trimming moment above the center of gravity, pound-feet
V	speed, feet per second
g	acceleration of gravity (32.2 ft/sec^2)
L	over-all length, distance from forepoint to sternpost, feet (associated with B)
d	draft at step, feet

H wave height, vertical distance from trough to crest, feet

L wave length, distance from crest to crest, feet (associated with b)

The most significant results of the tests are shown in figures 20 and 21. In carrying out the tests with three wave heights as well as in smooth water, it was found that the spray tended to increase with wave size. For this reason only the results of the tests conducted in waves with a height of 0.3 beam are included in this report.

Figure 20 presents a photographic study of the effect of changes in hull form on bow-spray characteristics. In this figure each column shows all the results for one model. At the top of each column is a direct head-on photograph of the model. Inasmuch as all the models were constructed with the same beam width and all the photograms were taken with the same camera at the same distance from the model, the apparent differences in size are caused by perspective and indicate the relative "fullness" of the bow in each case. The pictures of the entire forebody were also taken under the same conditions and the apparent differences again indicate the relative fullness. The lower three photographs show the spray for each of the three values of C_{Δ}. The photographs are arranged in the figure in such a manner as to permit a study of the effects of each of the six variables tested. The large differences in the spray characteristics of the various models indicate that adverse characteristics may be alleviated by proper choice of hull form.

It is also to be noted in figure 20 that a reduction in spray height results from the reduction of the water-borne load. Reduction of the bow spray in this manner, however, is not nearly as effective as small changes in hull form are shown to be. It should be further noted that penalizing the load-carrying capacity of a flying boat to overcome adverse bow spray should not be considered a satisfactory answer to the problem and may be considered at best only a temporary expedient for overcoming adverse bow-spray characteristics encountered by existing flying boats.

Figure 21 presents the results of the tests on the series of four models differing in length-beam ratio in which the loading was progressively increased in each case until the model sank.

Considering both figures 20 and 21, and neglecting the effect of change of the water-borne load for reasons previously mentioned, it appears that the principal effects on the bow spray of the variables studied may be put into three groups; the effect of forebody length, the effect of sharpness of the bow, and the effect of changes of static trim.

Effect of Forebody Length

The tests with altered forebody length were actually made with models in which both the forebody and the afterbody length were altered in the same proportion. This was done to avoid alterations in static trim due to changes in the relative bouyancy of the two parts.

It is evident from the results that the bow spray is greatly reduced by lengthening the hull. The beneficial effect of decreasing the values of C_Δ, without altering the hull length, is also evident. So far as load per length is concerned, an increase in hull length without a corresponding increase in C_Δ is equivalent to a reduction of loading without an increase in hull length. It will be seen from figure 21, however, that the maximum practicable loading, or the load for equivalent bow spray, increases much more rapidly than in direct proportion to the increase in length and that the beneficial results obtained from increasing the forebody are therefore greater than can be accounted for by reduction of loading per unit length of hull. This point is well illustrated by comparing the photos in figure 21 for $L/B = 5.07$, $C_\Delta = 0.60$, and $L/B = 8.45$, $C_\Delta = 1.00$, where $\frac{8.45}{5.07} = 1.67$ and $\frac{1.00}{0.60} = 1.67$. Under these conditions the load per unit length is identical for the two hulls but the spray characteristics are much better for the longer hull. The probable explanation of the extra benefit lies in the reduced curvature of buttocks lines which softens the impact between the hull and the waves and reduces "suction effect."

Effect of Sharpness of Bow

The sharpness of the bow is, admittedly, a very vague and uncertain description of hull form. The term is suggested chiefly by the very excellent behavior of Models Nos. 401-1 and 441-1 (XPBB-1), both of which have very large angles of dead rise near the bow and sharp entrance angles of the water planes, but the term is construed to include also the effect on the bow of warping of the forebody bottom and changing of the hull dead rise as a whole.

The lines of the two models previously mentioned differ in that Model No. 441 has a lot of chine flare; whereas Model No. 401 has very little. The effect of this difference does not seem to be reflected in the behaviour of the two models, and there is nothing in the tests of the other models which throws additional light on the effect of chine flare.

Models Nos. 417-29 and 339-47 both have "sharper" bows than the parent XPB2M-1 and both have lower bow spray. Models Nos. 339-18 and 400-1 both have bows that are not as "sharp" as the parent XPB2M-1 and in both cases the spray is higher. This is particularly true of Model No. 339-18. Model No. 339-41 has bow sections quite similar to the parent and the spray is much the same.

One exception to this trend is noted in the spray height of Model No. 339-39. This model was derived in the same manner as Model No. 339-41. Although the bow of this model was not as "sharp" as that of the parent, the spray was lower. The range of the tests was such that no satisfactory explanation of this reversal of trend was forthcoming.

Effect of Changes of Static Trim

Basically, there are three methods of altering the static trim: by application of an external moment to the hull by shifting the center of gravity (aerodynamic and thrust moments together will ordinarily have little effect on trim at low speeds), by altering the bouyant power of the afterbody alone, or by altering the bouyant power of the forebody alone.

Shifting of the center of gravity is very likely, however, to have undesirable effect on the available trim control at planing speeds. In practice the center of gravity has to be selected so as to give an available trim track which does not pass through a region of porpoising. Therefore it does not appear logical to shift the center of gravity to improve the bow-spray characteristics at the expense of the planing characteristics.

The second method of altering the static trim is most easily accomplished by altering the afterbody angle. If, with an altered afterbody angle, the position of the center of gravity is unaltered, then the available trim tracks at planing speeds also will be largely unaltered relative to the porpoising limits. Altering the afterbody angle, however, usually alters the hump resistance and the porpoising characteristics at speeds in the vicinity of the hump. Thus, altering the afterbody angle is like altering the position of the center of gravity in that any improvement effected at low speeds is apt to be at the expense of the other characteristics. It is, however, much less undesirable in this respect, and was accordingly adopted for the present tests. The effect of changing the static trim by altering the afterbody angle is shown in the first and last two columns of figure 20. Increasing the static trim in this way makes a small but noticeable improvement in the spray characteristics. It does not make nearly as large improvements as can be produced by altering the hull form, particularly the bow section.

The third method of altering the static trim, by altering the buoyant power of the forebody alone and keeping the afterbody angle constant, may be accomplished both by altering the dead rise and the "fineness" of the bow sections. Increasing either of these decreases the buoyancy of the forebody and consequently reduces the trim angle. Both of these changes improve the spray characteristics, however, and therefore more than offset any deleterious effect of decreasing the trim, as such.

The conclusion that an increase of trim angle does not necessarily result in reduced spray, and vice versa, is confirmed by the fact that Model No. 339-18 had just about the highest static trim of any of the models tested and also had the worst spray characteristics. On the other hand, the spray height can probably be decreased with any given bow form by increasing the static trim, at least when the form under consideration has reasonably bad spray characteristics.

General Discussion

The really marked benefits observed in reduction of bow spray in these tests are all due to changes in the hull form, rather than to changes of load or trim, and particularly to changes in the forebody, especially the forward quarter or less of the forebody. The importance of the bow sections of the forebody can be most readily seen from the results obtained with Model No. 339-47, which had only a few inches of the bow changed and showed a considerable improvement over its parent, Model No. 339-1. The conception that the forward part of the forebody is all that has to be considered in designing a hull for good performance in rough water at low speeds is a very useful one. Development work may proceed on the other hydrodynamic characteristics of the rear half of the forebody without paying any particular attention to the bow section, or vice versa. Tests conducted at Stevens Institute of Technology for the National Advisory Committee for Aeronautics have shown that the first two beam lengths or so of the forebody ahead of the main step appear to control the hump resistance and the high-speed lower-limit porpoising characteristics of a hull. It appears, therefore, that the forebody may be divided into two halves from the design standpoint. The forward half can be designed from the point of view of the low-speed rough-water characteristics primarily, and the after half of the forebody from the point of view of the hump resistance and lower-limit porpoising characteristics. In designing the forward part of the forebody to reduce spray at the windshield, care should be taken to select a form which will give easy entry into waves encountered head-on.

There is very good qualitative agreement between the tests here reported and available full-scale data. For instance, Model No. 441-1, which represents the XPBB-1, shows up very well; while no exact information is at hand regarding the flying boat, it was reported to be quite satisfactory in waves at taxying speeds. Model No. 339-1, which represents the XPB2M-1, is not entirely satisfactory and water sometimes gets onto the model windshield under certain conditions; full-scale experience bears out this indication. These two specific examples indicate that confidence may be placed in the present test results, since the model tests are in agreement with full scale both in an instance of satisfactory bow-spray characteristics and in an instance of unsatisfactory bow-spray characteristics.

CONCLUSIONS

1. The tests indicate that the height and the volume of spray at the windshield may be reduced by:

a) Increasing the hull length. It seems clear that when this is done the change in the forebody length is much more important than the change in the afterbody length. Increasing the forebody length reduces the draft and straightens the buttocks.

b) Increasing the sharpness of the bow lines below the chine, with or without pronounced chine flare. This may be accomplished by increasing the dead rise angles in the vicinity of the bow or by sharpening the water lines. Both changes ease the entry of the bow into the waves.

c) Increasing the static trim angle when the bow form is such that relatively bad spray otherwise occurs. By raising the bow the point of impact is moved somewhat, and at the same time the force of the impact with the oncoming waves is reduced.

d) Decreasing the static C_Δ, which has effects similar to those noted under (c) above.

2. The largest benefits observed are all due to changes of the forebody form and especially to the forward part of the forebody. This is particularly important in that it appears that satisfactory bow-spray characteristics may be obtained without compromising the planing characteristics. Further, in general, any change which softens the impact between hull and waves tends to reduce the spray thrown onto the windshield at low speeds.

Experimental Towing Tank,
Stevens Institute of Technology,
Hoboken, N. J., August 1943.

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TABLE I

Model No.	Beam at Step ins.	Forebody Length ins.	Afterbody Length ins.	Deadrise at Step and Keel deg.	Deadrise 1/2b aft of F.P. at Keel deg.	Step Height % b	Afterbody Angle deg.	Description
339-1	5.40	18.60	14.85	20	52.0°	5.0	7.0	XPB2M-1, "Parent"
417-29	"	18.87	16.78	"	55.2°	5.0	7.0	"JRM-1"
441-1	"	19.43	14.40	"	67.5°	9.0	5.5	XPBB-1
339-22	"	15.10	12.15	"	47.5°	5.0	7.0	L/B = 5.07
339-23	"	21.98	17.55	"	52.7°	"	"	L/B = 7.32
339-46	"	25.23	20.25	"	53.2°	"	"	L/B = 8.45
400-1	"	17.78	14.85	10	24.5°	"	"	Deadrise 10°
401-1	"	18.60	"	30	73.2°	"	"	Deadrise 30°
339-39	"	18.60	"	20	35.7°	"	"	Forebody Warped 5.4°/b
339-41	"	18.60	"	"	51.8°	"	"	Forebody Warped 10.8°/b
339-18	"	18.51	"	"	40.0°	"	"	Full Bow
339-47	"	18.60	"	"	56.2°	"	"	Fine Bow
339-29	"	18.60	"	"	52.0°	"	5.0	Afterbody Angle
339-48	"	18.60	"	"	52.0°	"	9.0	Afterbody Angle

NOTE: In all cases the trim angles are measured relative to the forebody keel tangency.

STATIC PROPERTIES

ACTUAL AIRPLANES

C.G. = 0.35 b fwd of Step
0.90 b above Keel

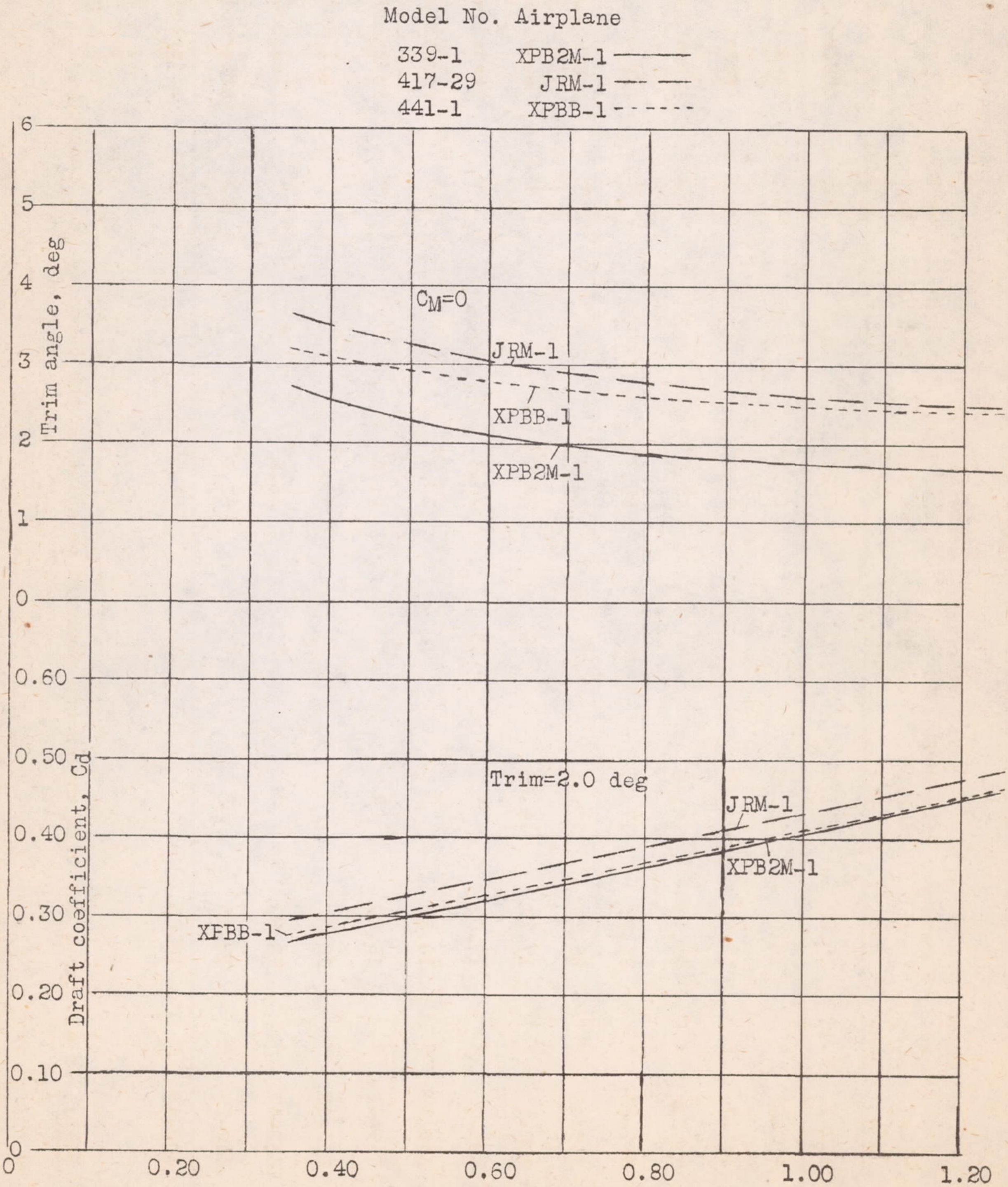
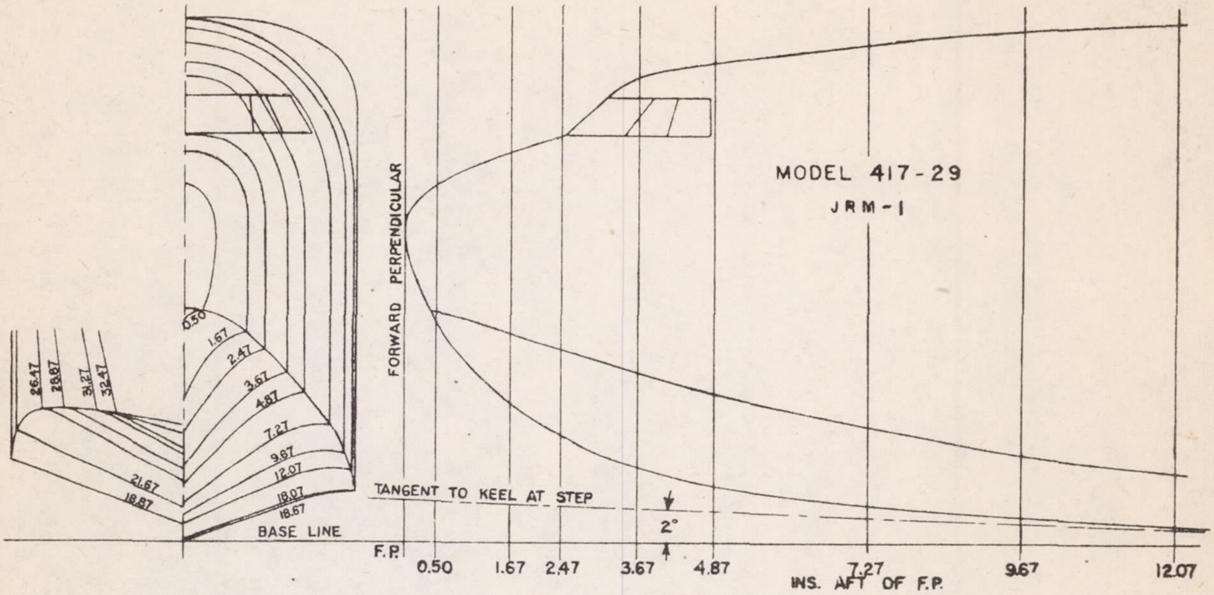
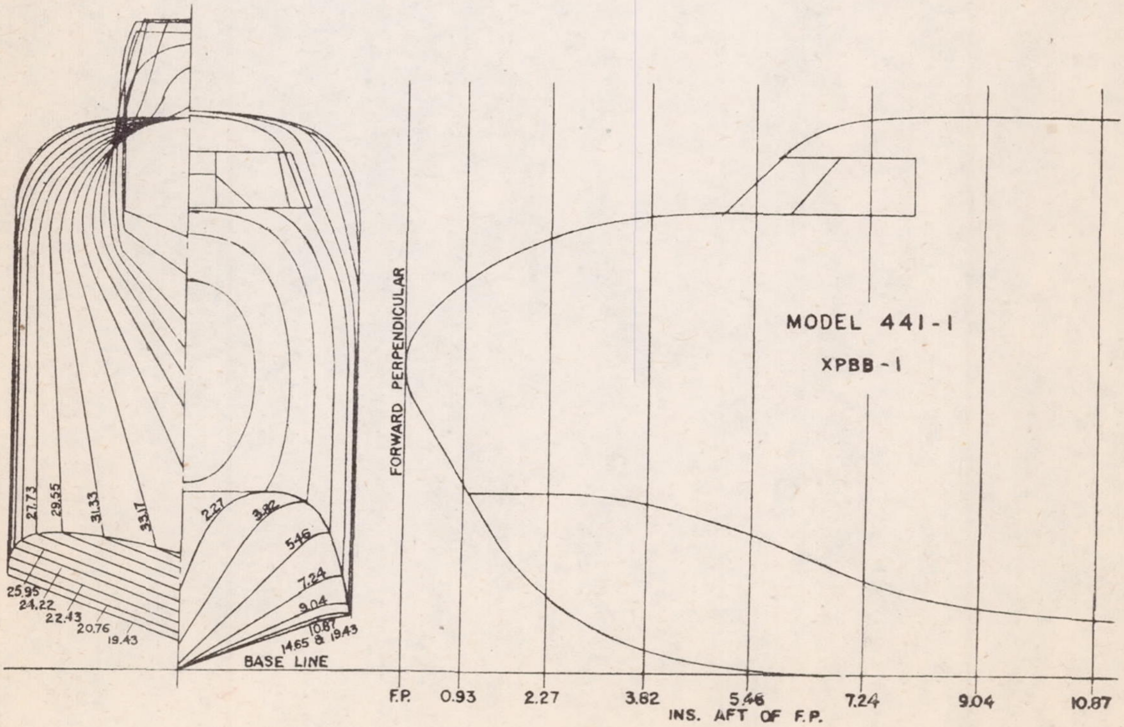


Figure 1.-



THE LINES OF MODEL NO. 339-1 (XPB2M-1) ARE ON FIGS. 4 AND 14



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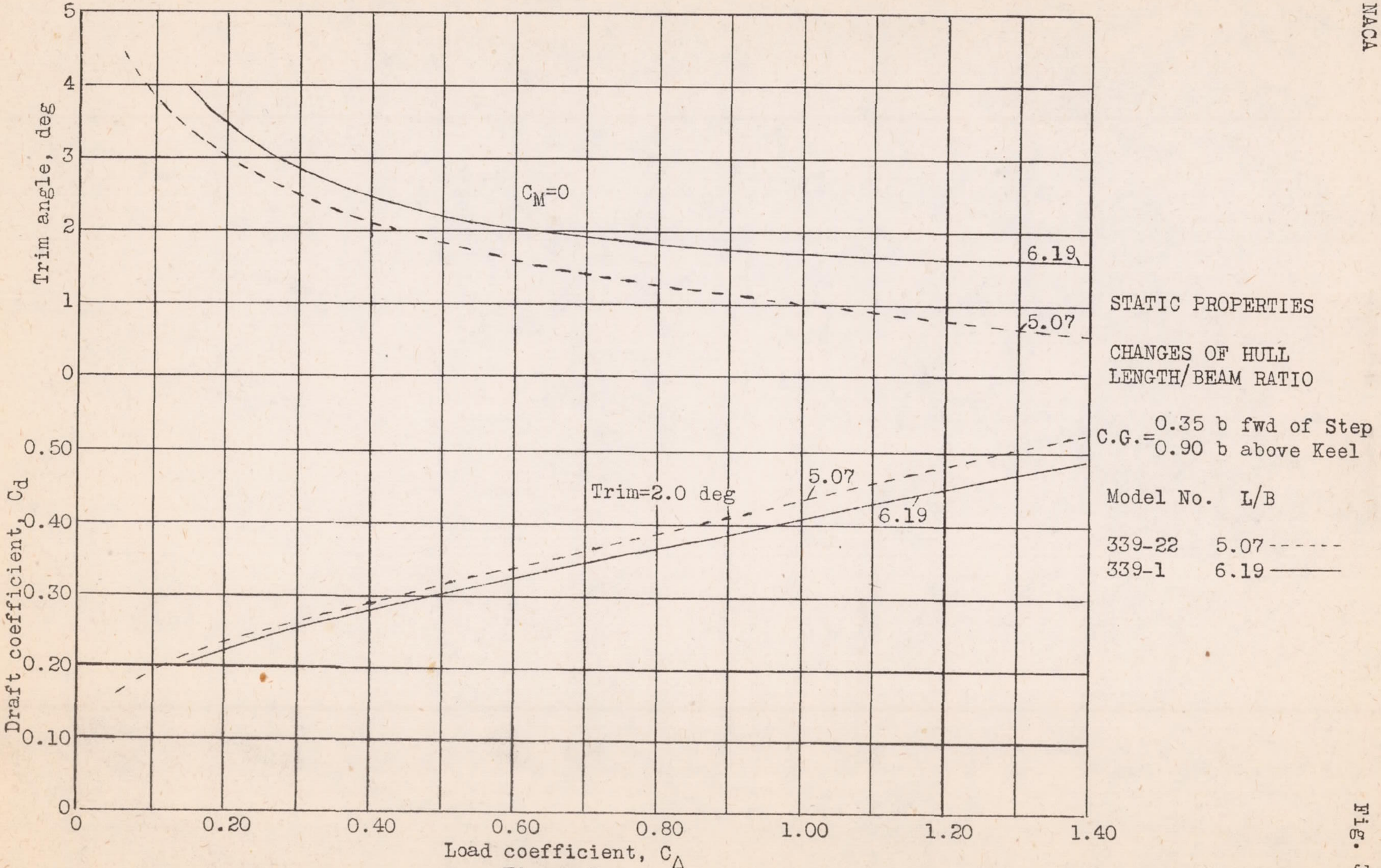


Figure 3.-

Fig. 3

W-71

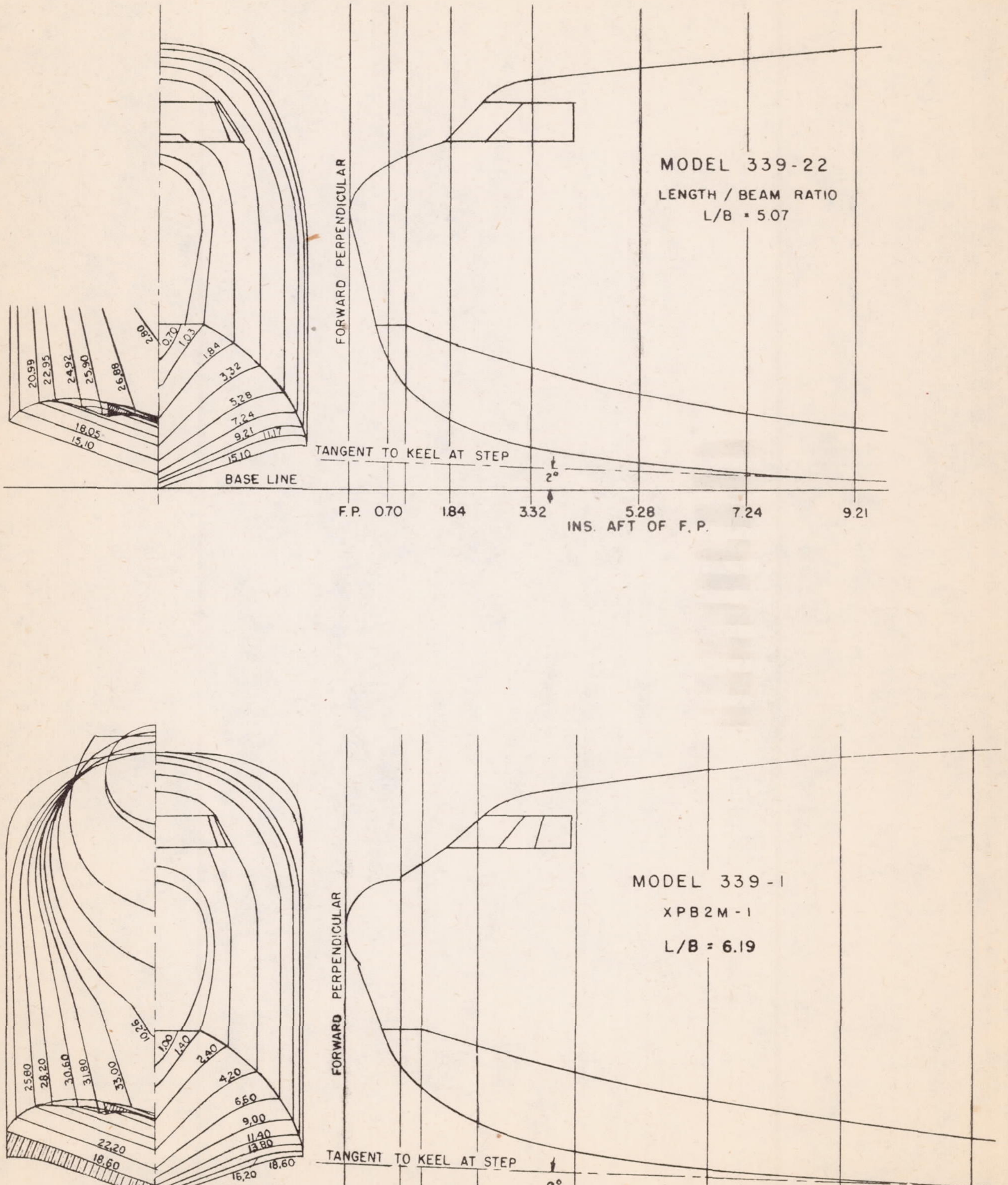
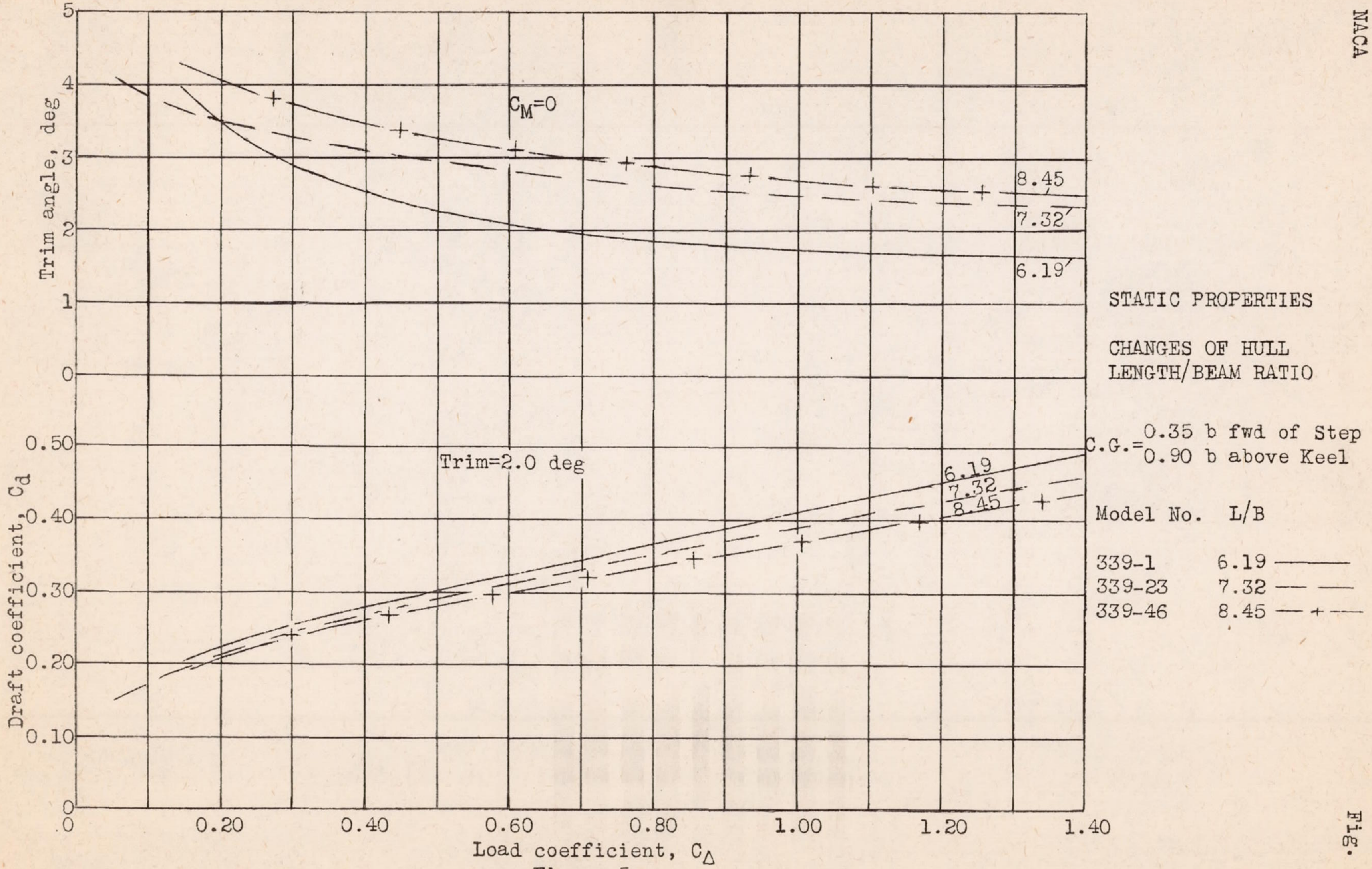

MODEL 339-22
LENGTH / BEAM RATIO
L/B = 5.07
FORWARD PERPENDICULAR
20.99
22.95
24.92
25.90
26.88
2.80
0.70
1.03
1.84
3.32
5.28
7.24
9.21
11.17
15.10
18.05
15.10
TANGENT TO KEEL AT STEP
2°
BASE LINE
F.P.
0.70
1.84
3.32
5.28
7.24
9.21
INS. AFT OF F. P.
MODEL 339-1
XPB2M-1
L/B = 6.19
FORWARD PERPENDICULAR
25.80
28.20
30.60
31.80
33.00
10.26
1.00
1.40
2.40
4.20
6.60
9.00
11.40
13.80
16.20
18.60
22.20
18.60
TANGENT TO KEEL AT STEP
2°
BASE LINE
F.P
1.40
2.40
4.20
6.60
9.00
11.40
INS AFT OF FP

Figure 4.

W-71



STATIC PROPERTIES

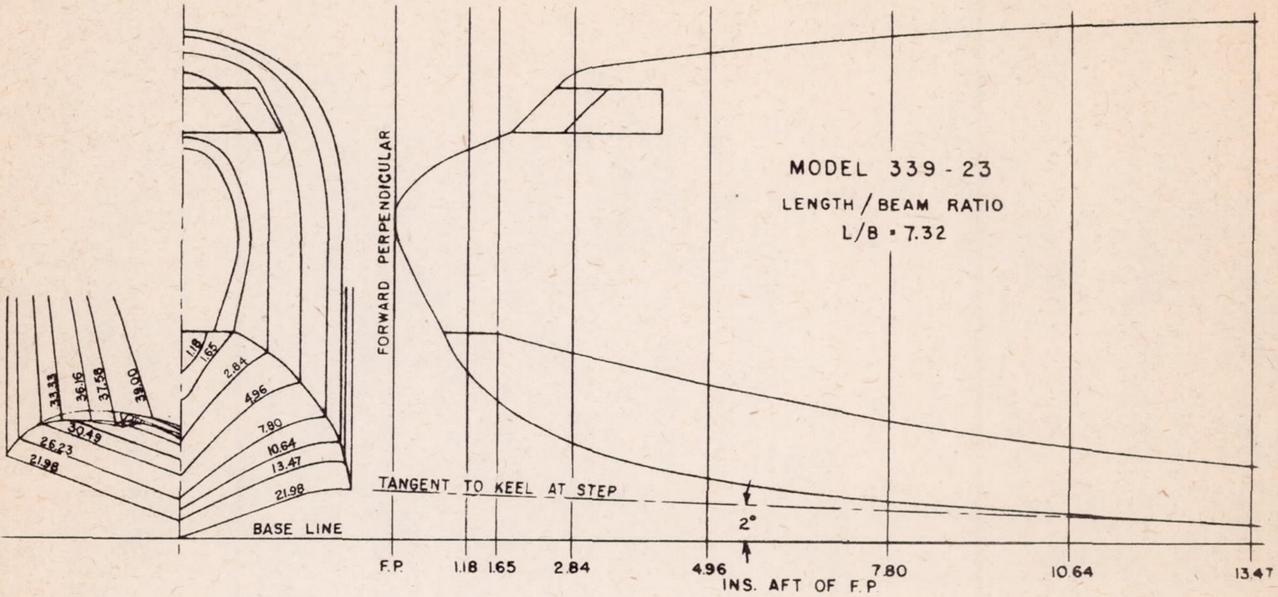
CHANGES OF HULL LENGTH/BEAM RATIO

C.G.= 0.35 b fwd of Step
0.90 b above Keel

Model No.	L/B
339-1	6.19 ———
339-23	7.32 — —
339-46	8.45 —+—

Figure 5.-

W-71



THE LINES OF THE PARENT, MODEL NO. 339-1, ON BOTTOM OF FIG. 4

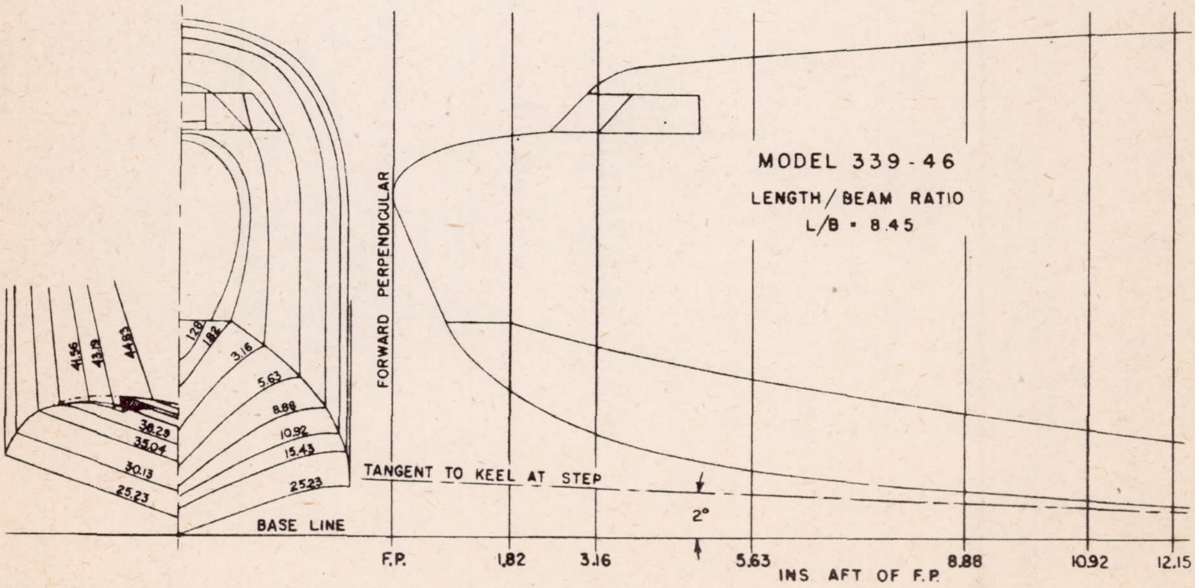
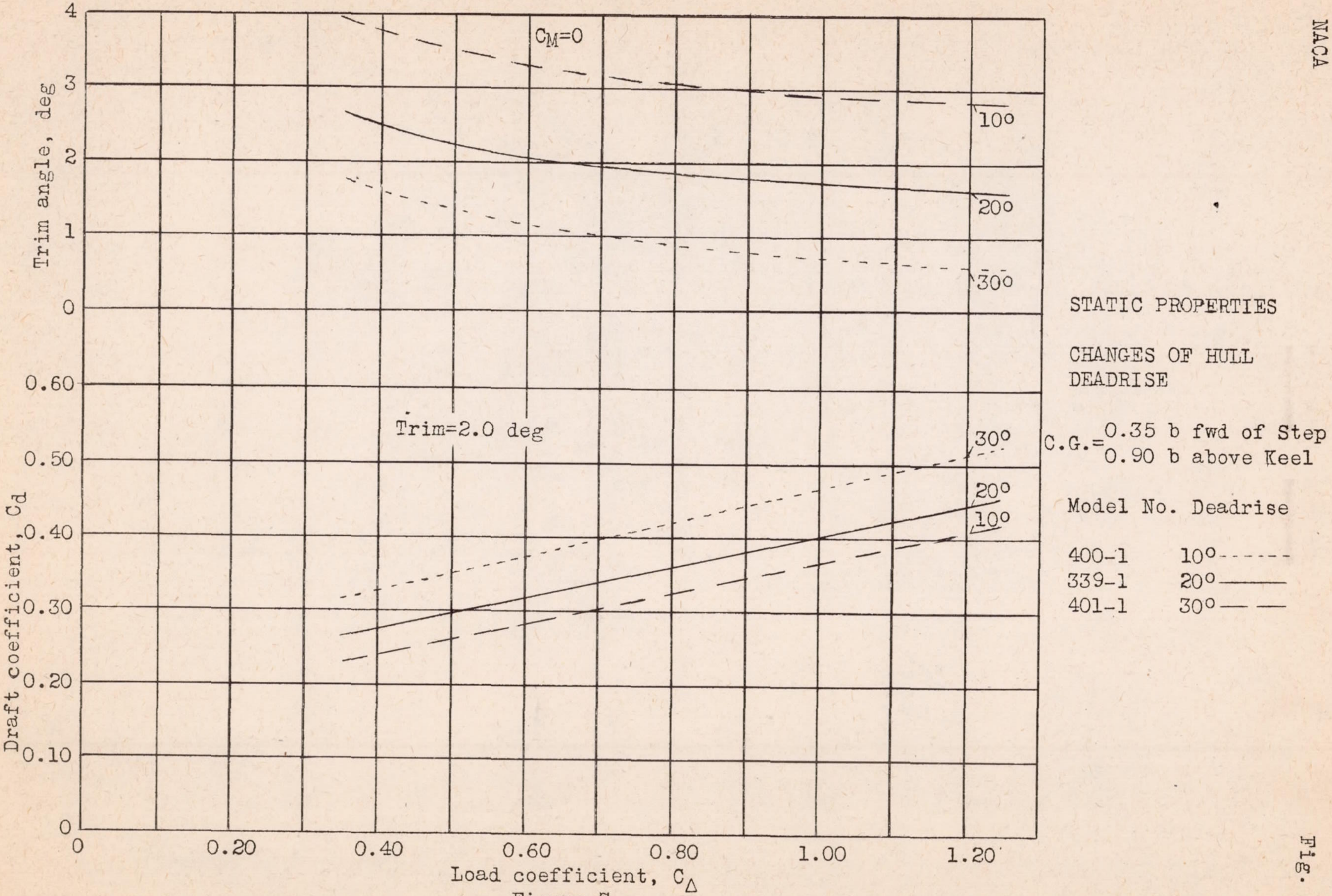


Figure 6.

W-71



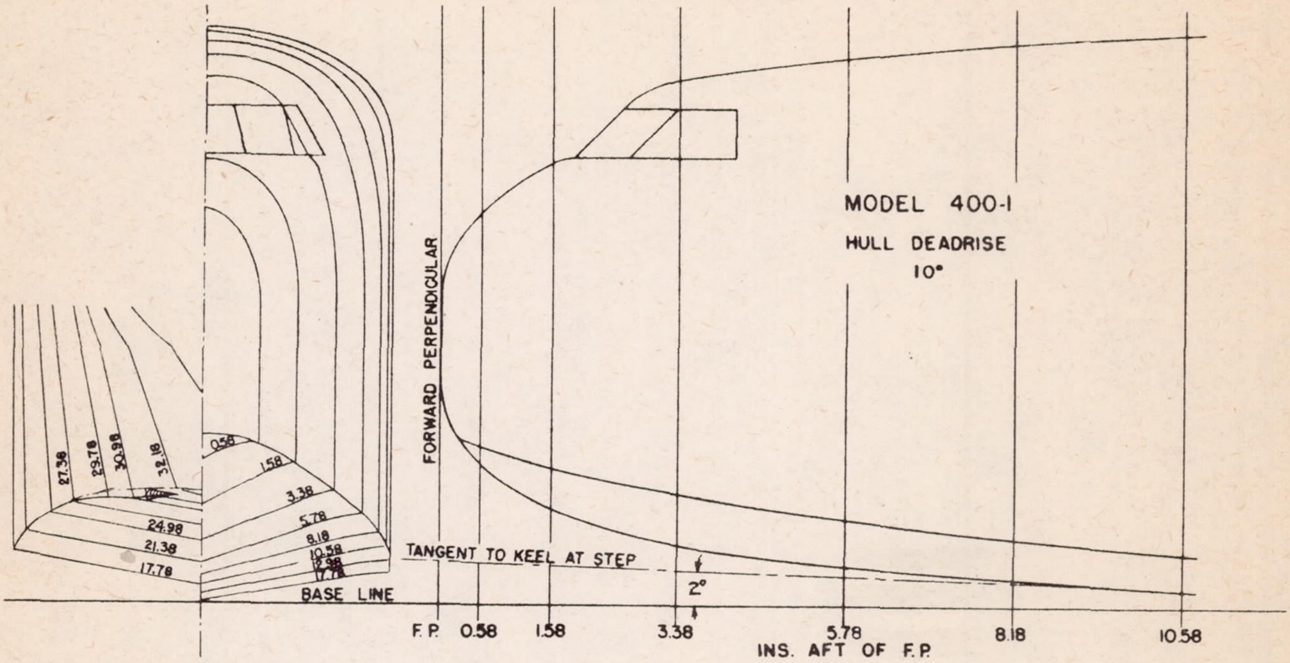
STATIC PROPERTIES

CHANGES OF HULL DEADRISE

C.G.= 0.35 b fwd of Step
0.90 b above Keel

Figure 7.-

W-71



THE LINES OF MODEL NO 339-1 (20° DEADRISE) ARE ON FIG. 14

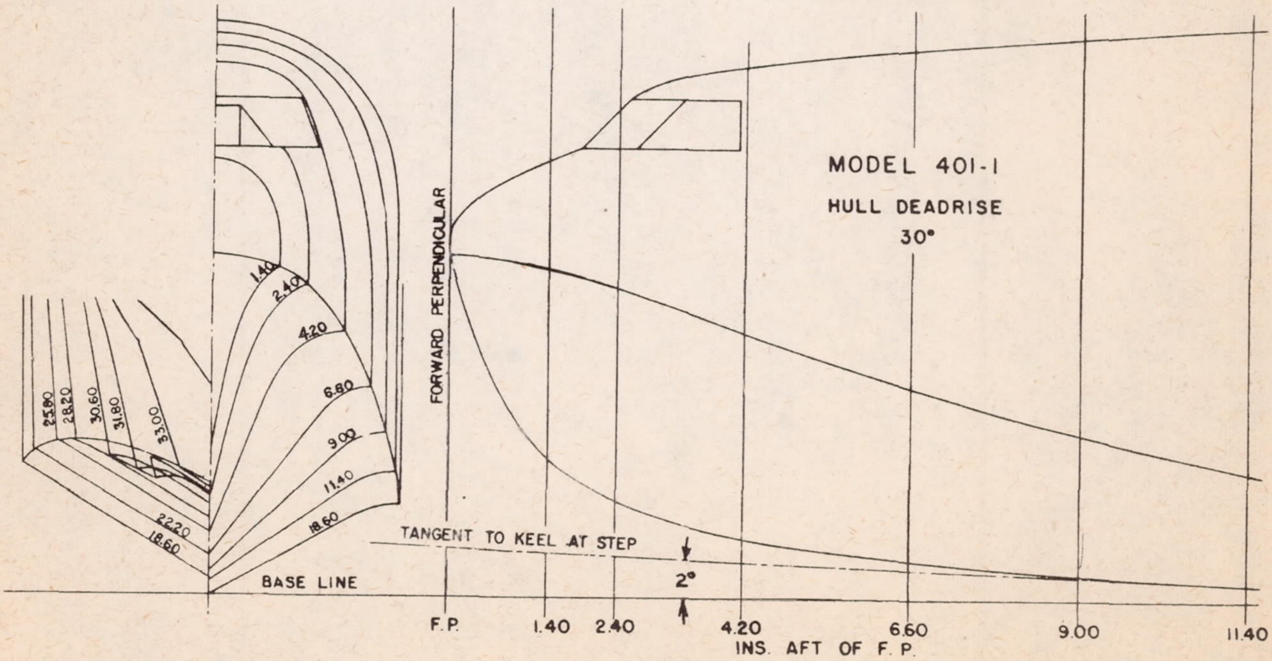


Figure 8.

W-71

NACA

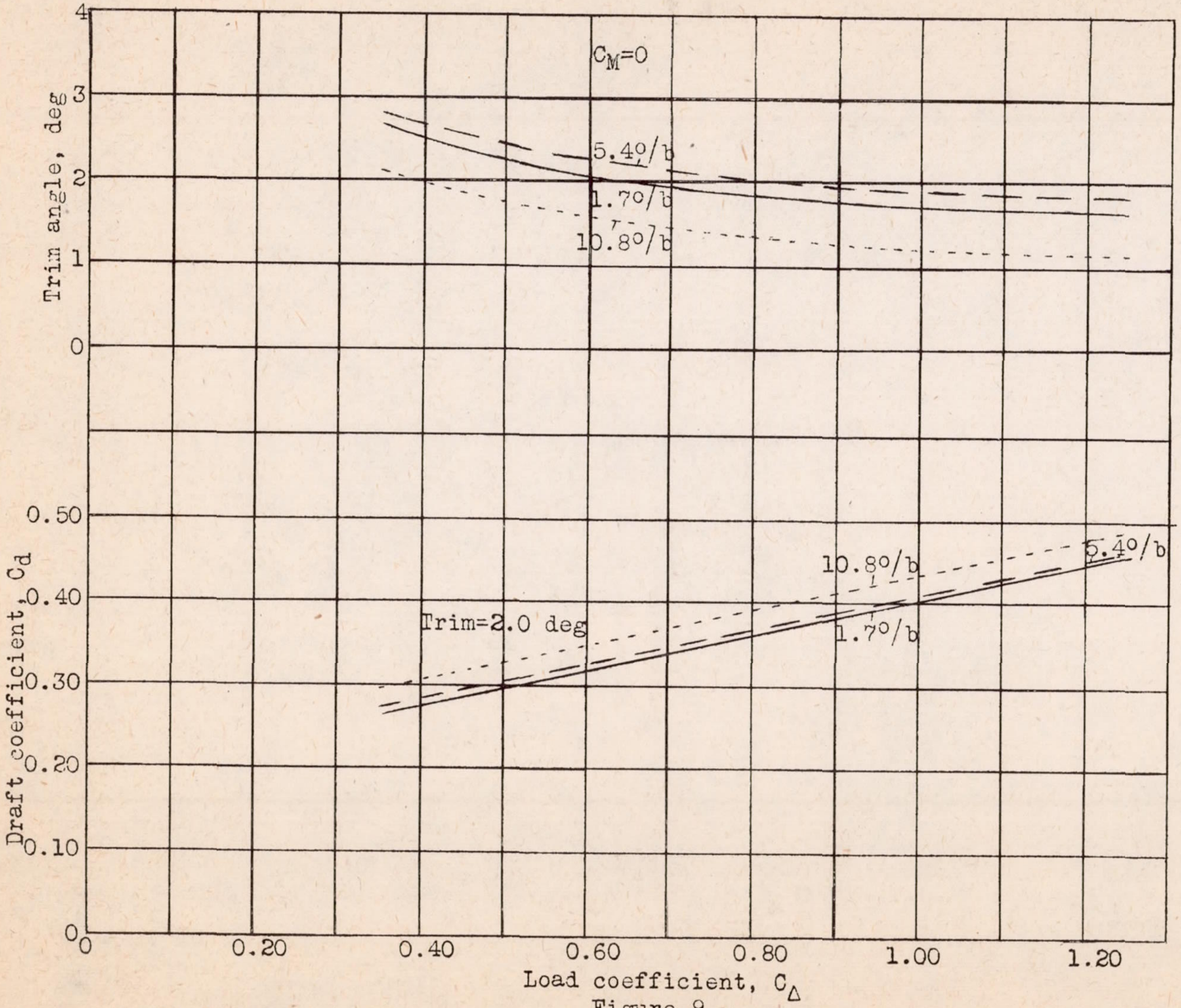


Figure 9.-

STATIC PROPERTIES

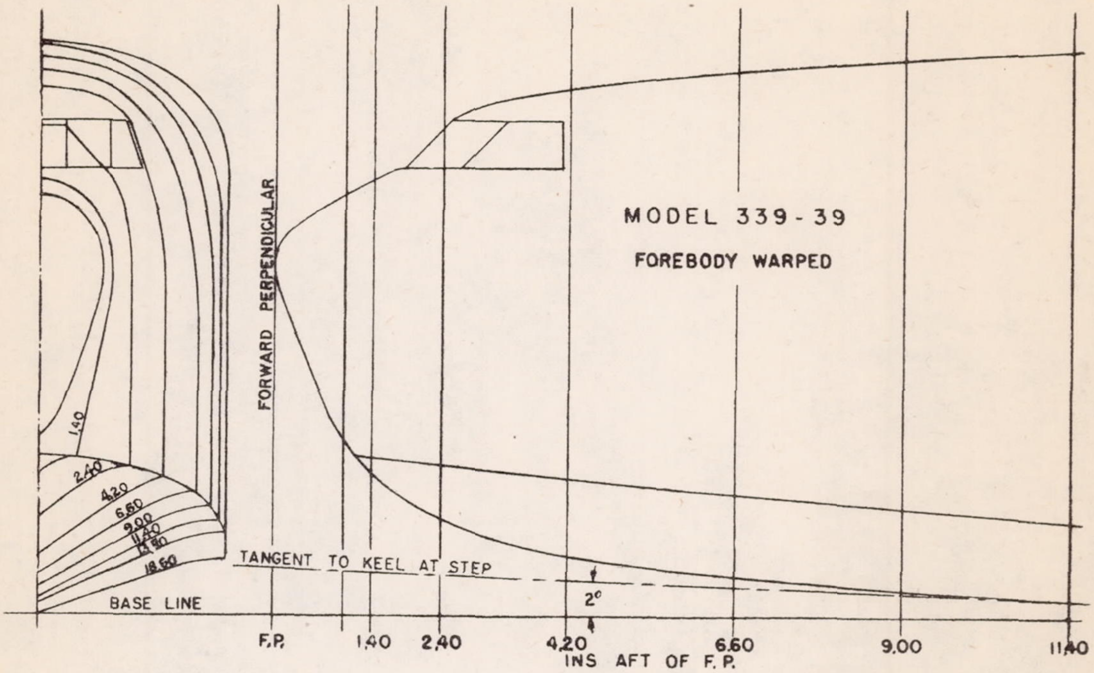
CHANGES OF FOREBODY WARPING

C.G.= 0.35 b fwd of Step
0.90 b above Keel

Model No.	Deadrise Increase FWD, °/beam	
339-1	1.7°/b	———
339-39	5.4°/b	— —
339-41	10.8°/b	- - - - -

Fig. 9

W-71



THE LINES OF MODEL NO. 339-1 (FROM WHICH THESE WERE DERIVED) ARE ON FIG. 14

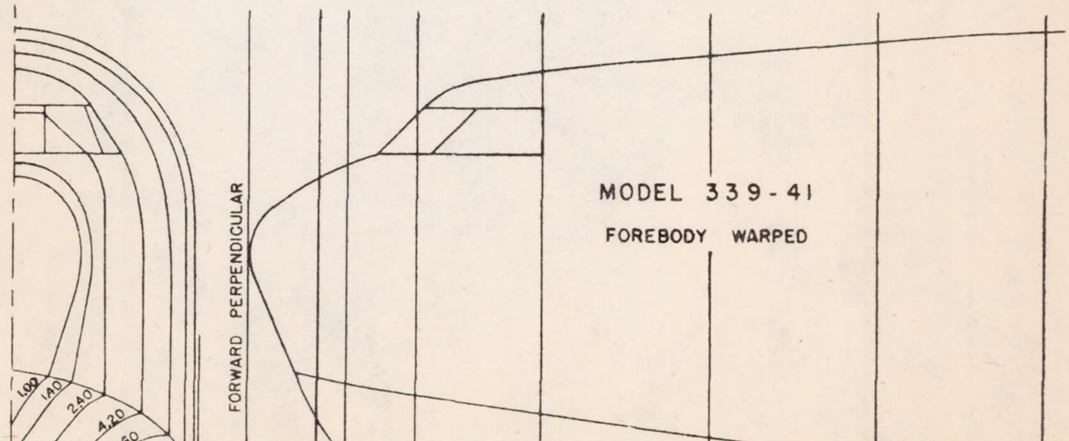
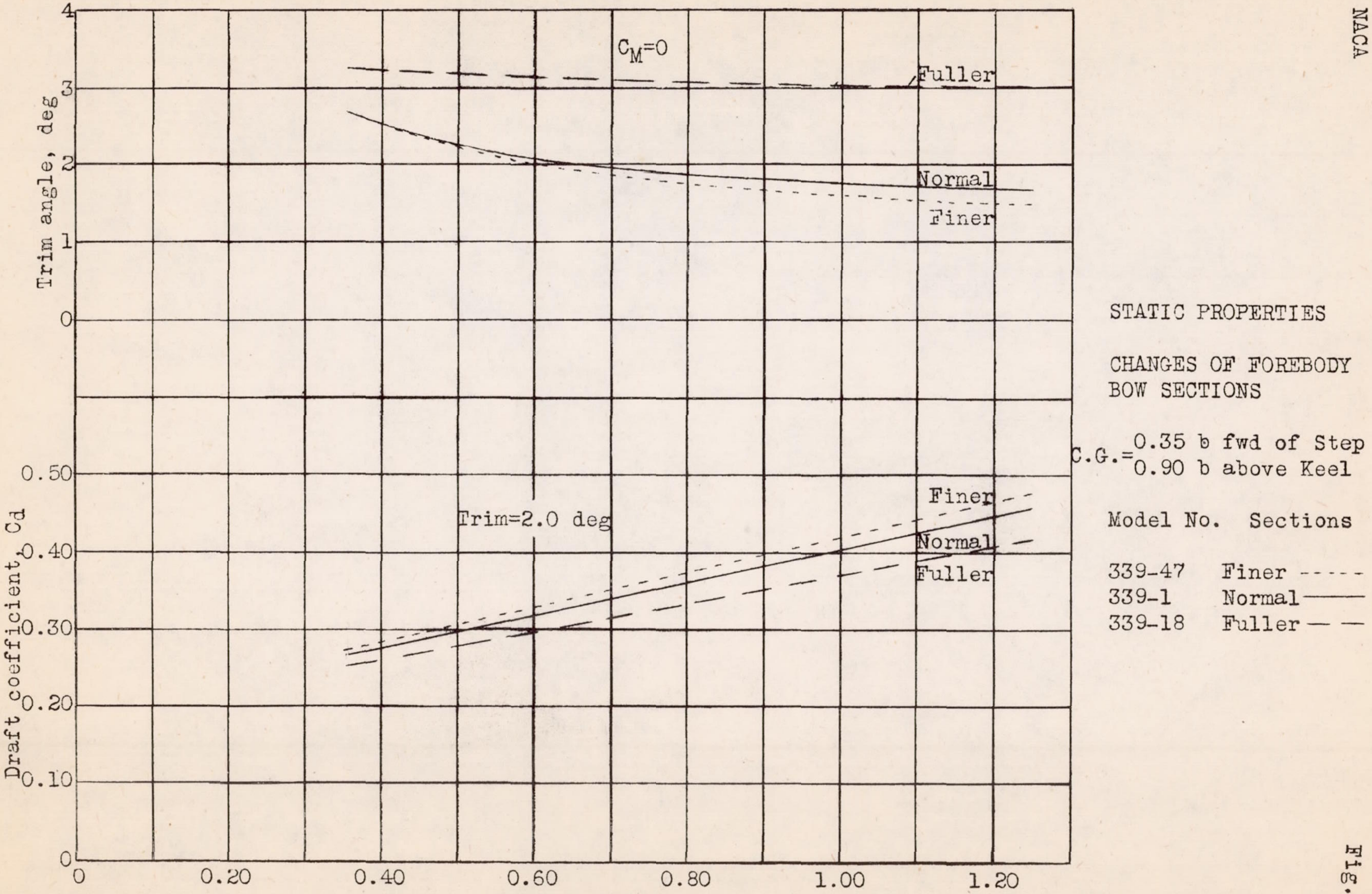


Figure 10.

W-71



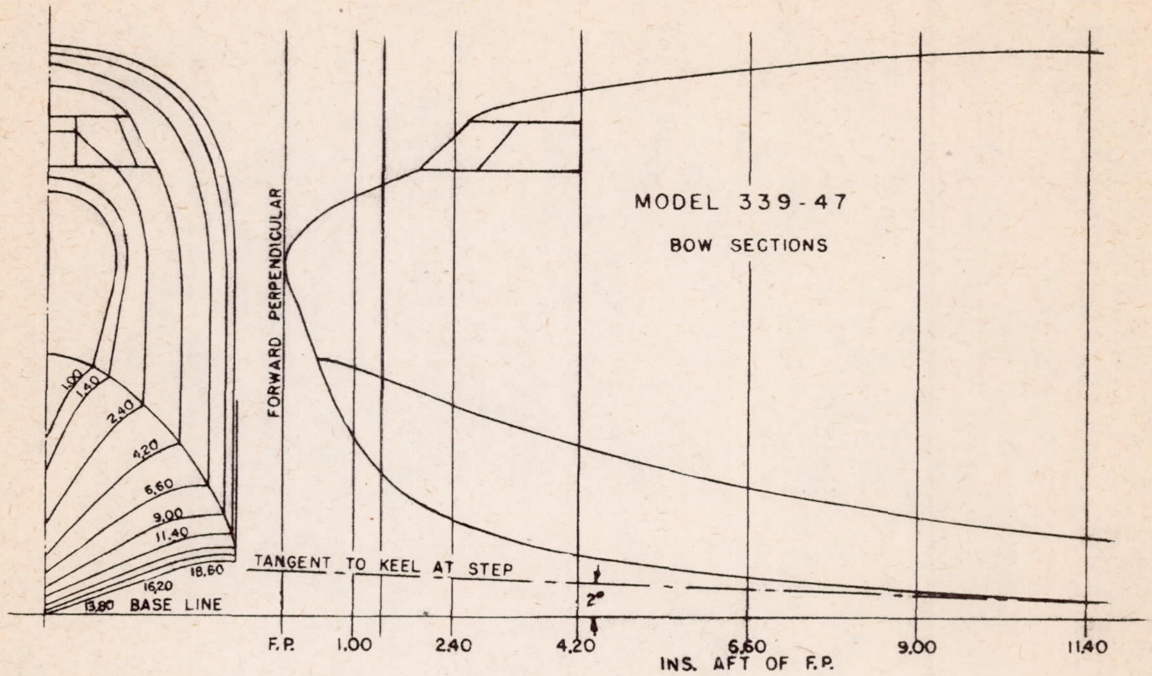
STATIC PROPERTIES

CHANGES OF FOREBODY BOW SECTIONS

C.G. = 0.35 b fwd of Step
0.90 b above Keel

Figure 11.-

W-7 1



THE LINES OF MODEL NO. 339-1 (FROM WHICH THESE WERE DERIVED) ARE ON FIG. 14

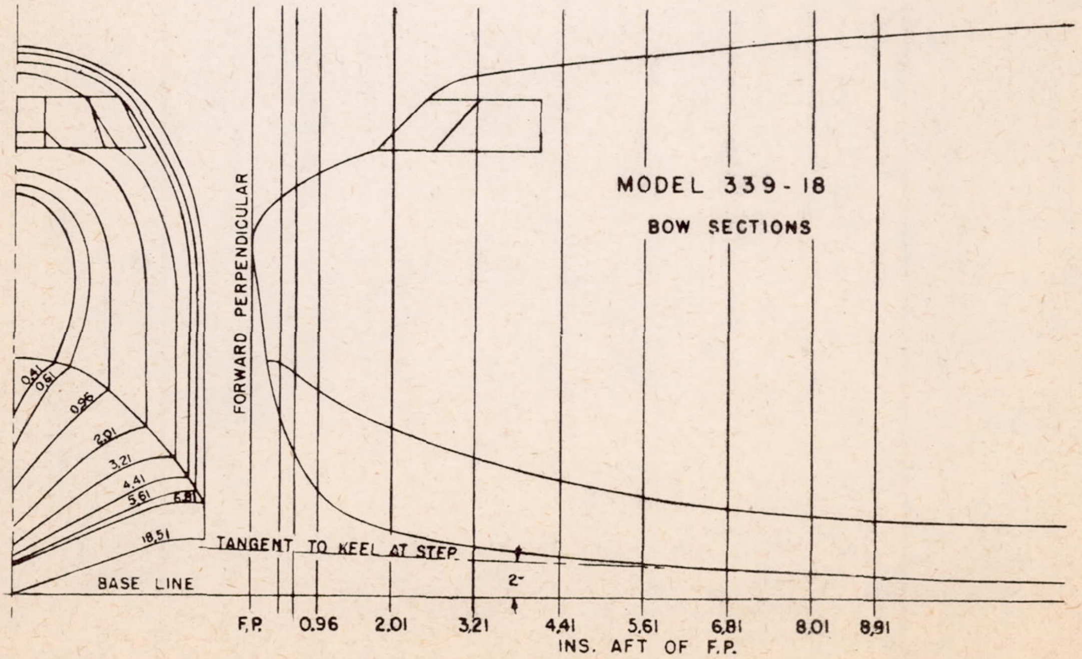


Figure 12

W-71

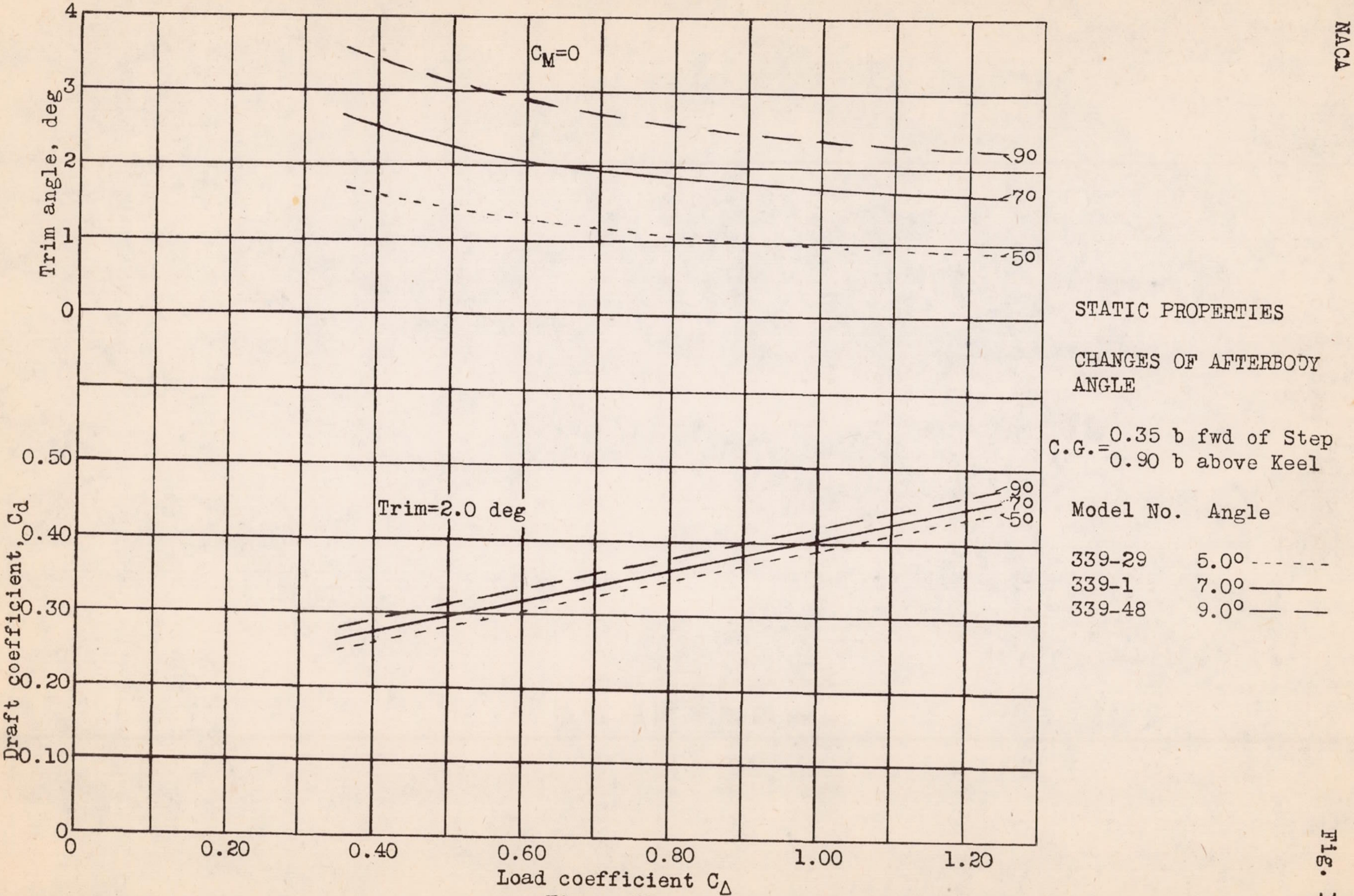
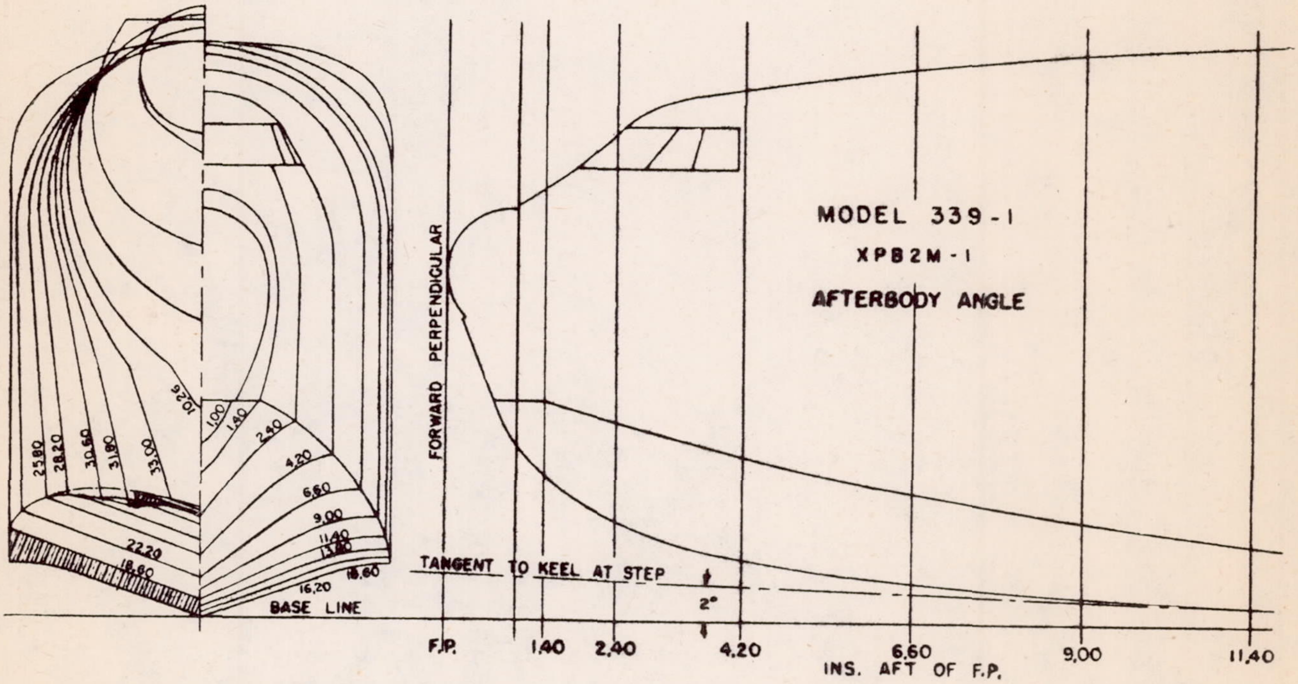


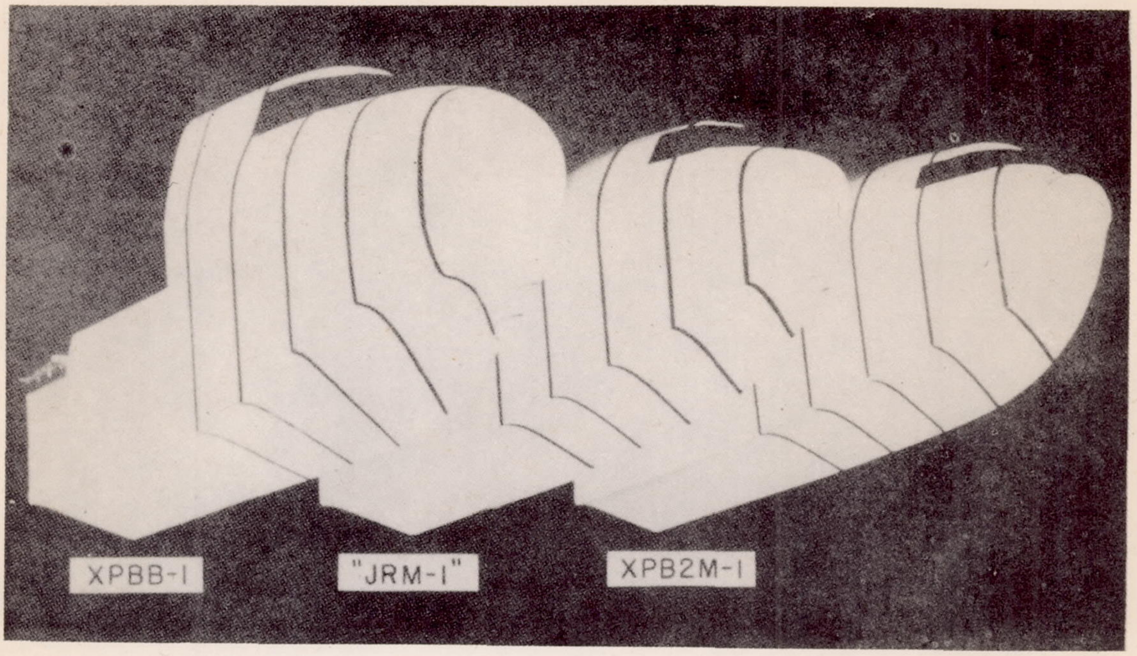
Figure 13.-

W-71

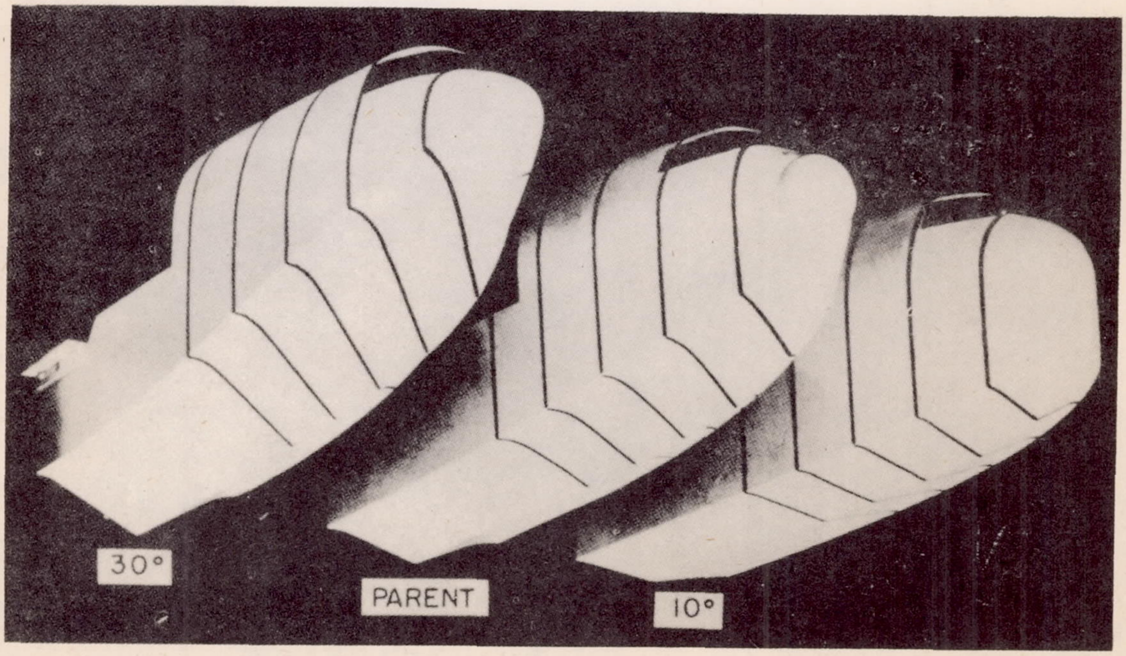


THE CHANGE IN AFTERBODY ANGLES RESULTING IN MODELS NOS. 339-29 AND 339-48 WAS ACCOMPLISHED BY ROTATING THE EXISTING AFTERBODY OF MODEL NO. 339-1 ABOUT THE STEP

Figure 14.



ACTUAL AIRPLANES Figure 15.



HULL DEADRISE Figure 16.

W-71

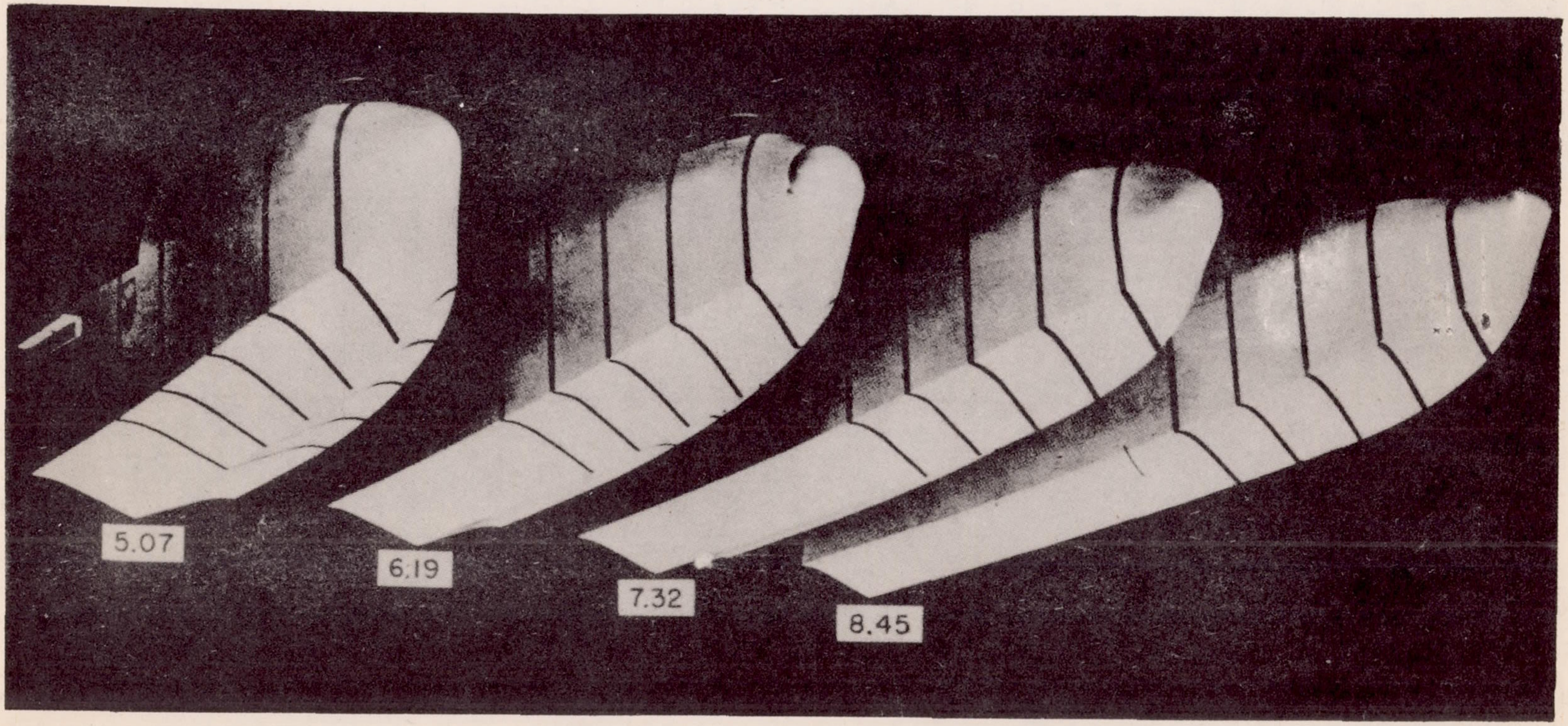
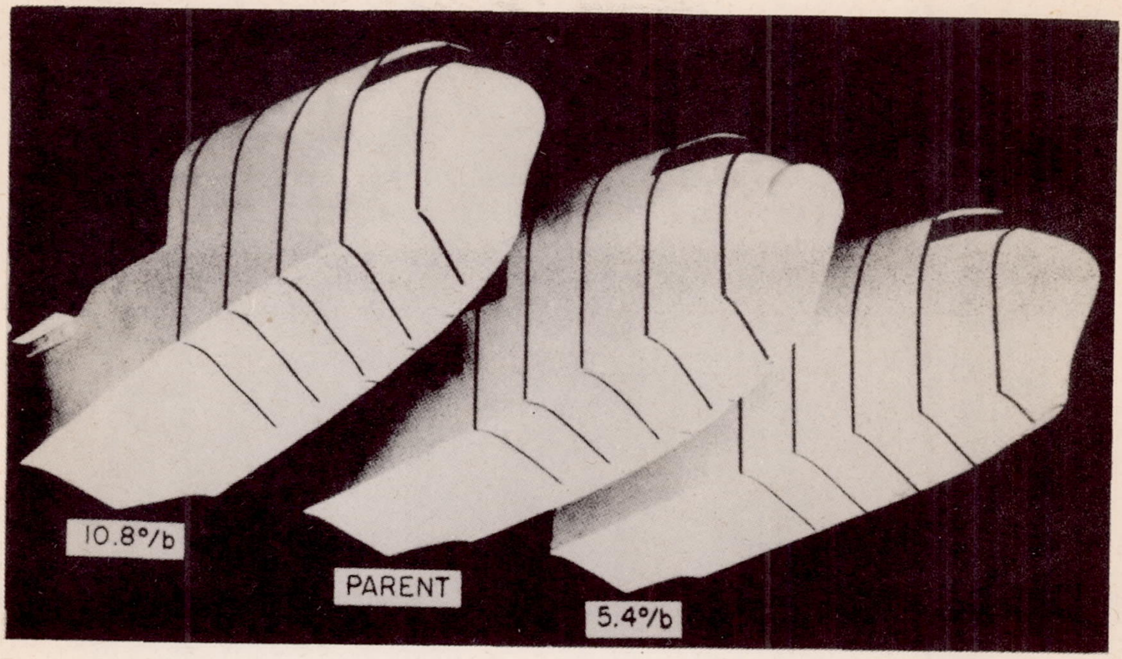
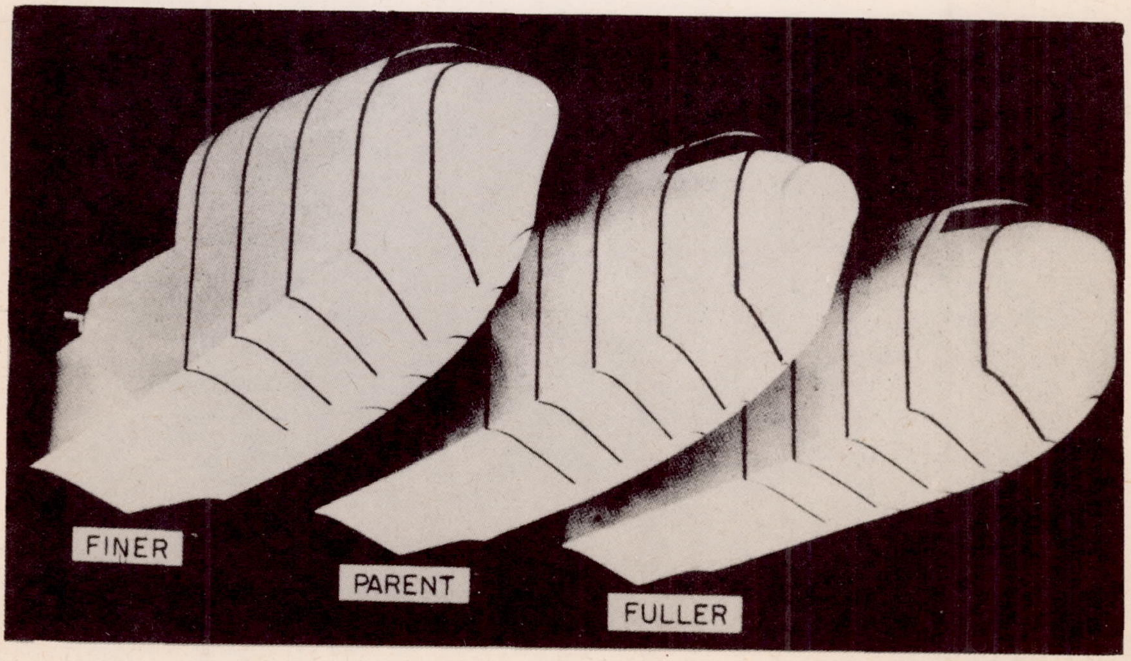


Figure 17. LENGTH-BEAM RATIO

W-71



FOREBODY WARPING Figure 1

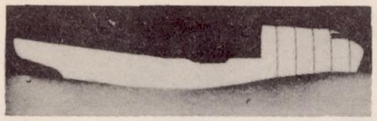


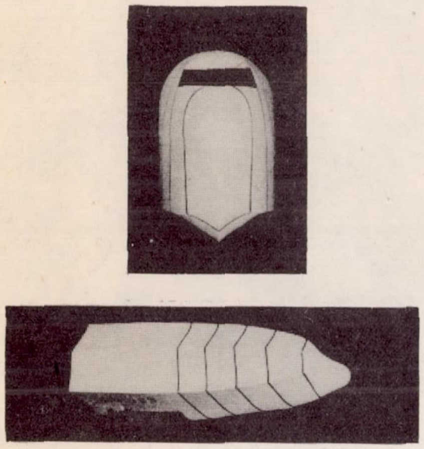
BOW SECTIONS Figure 19.

W-71

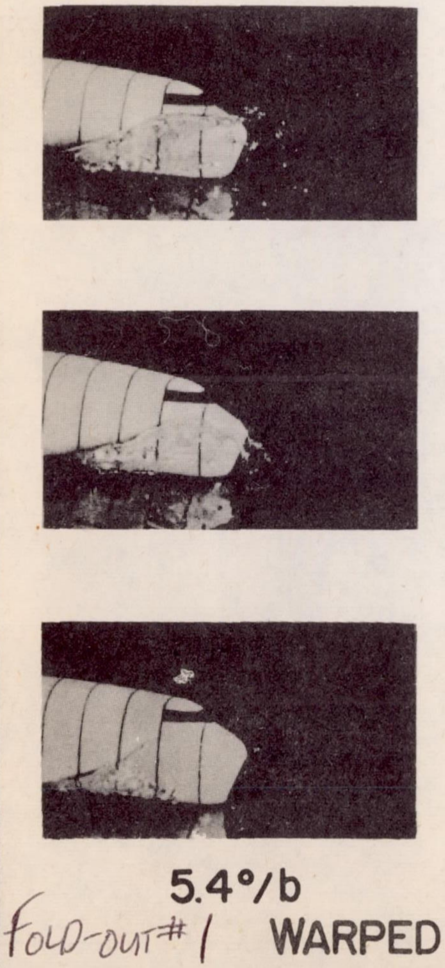
EFFECT OF CHANGES OF HULL FORM

H=0.3beam   L=6.0 beam

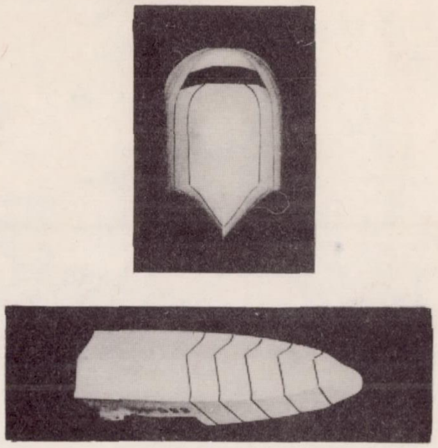




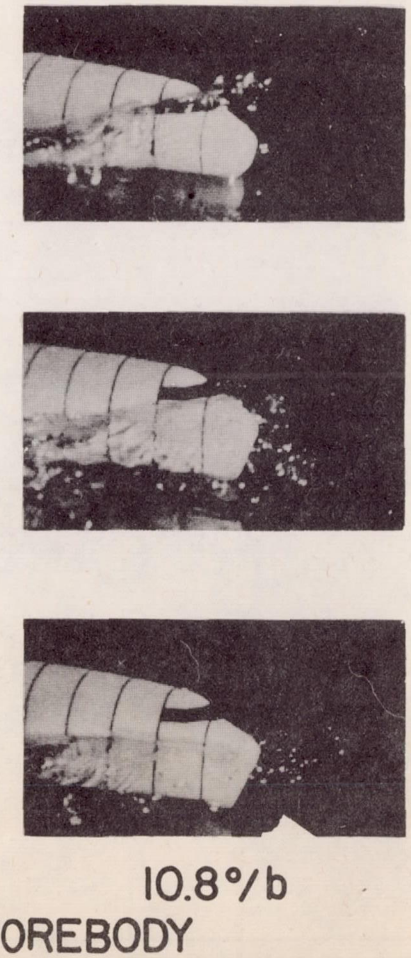
339-39



5.4°/b

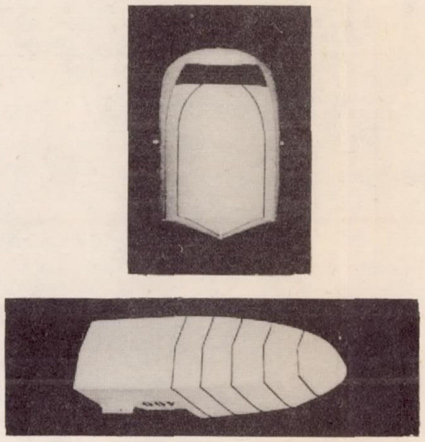


339-41

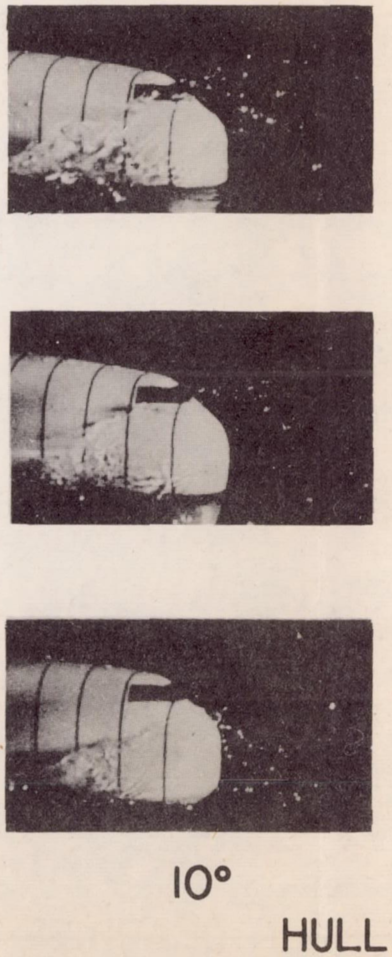


10.8°/b

Fold-out #1 WARPED FOREBODY

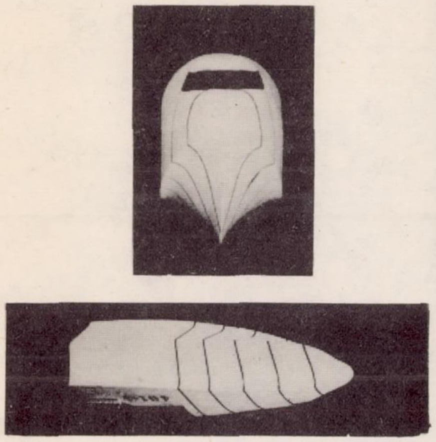


400-1

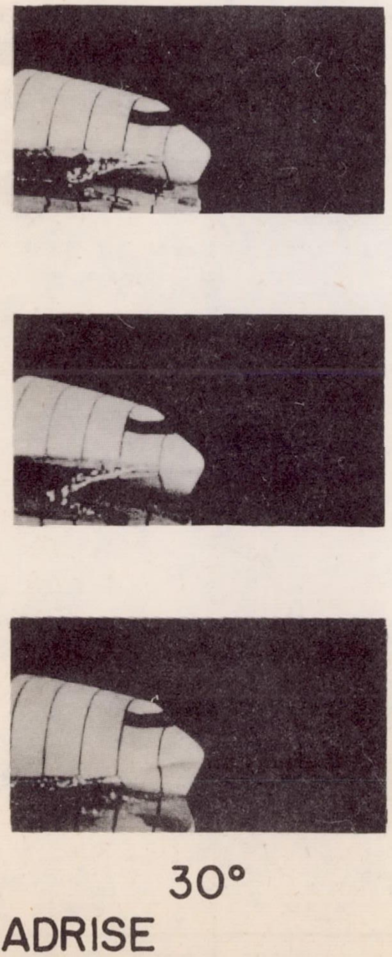


10°

XPB2M-1 "PARENT"



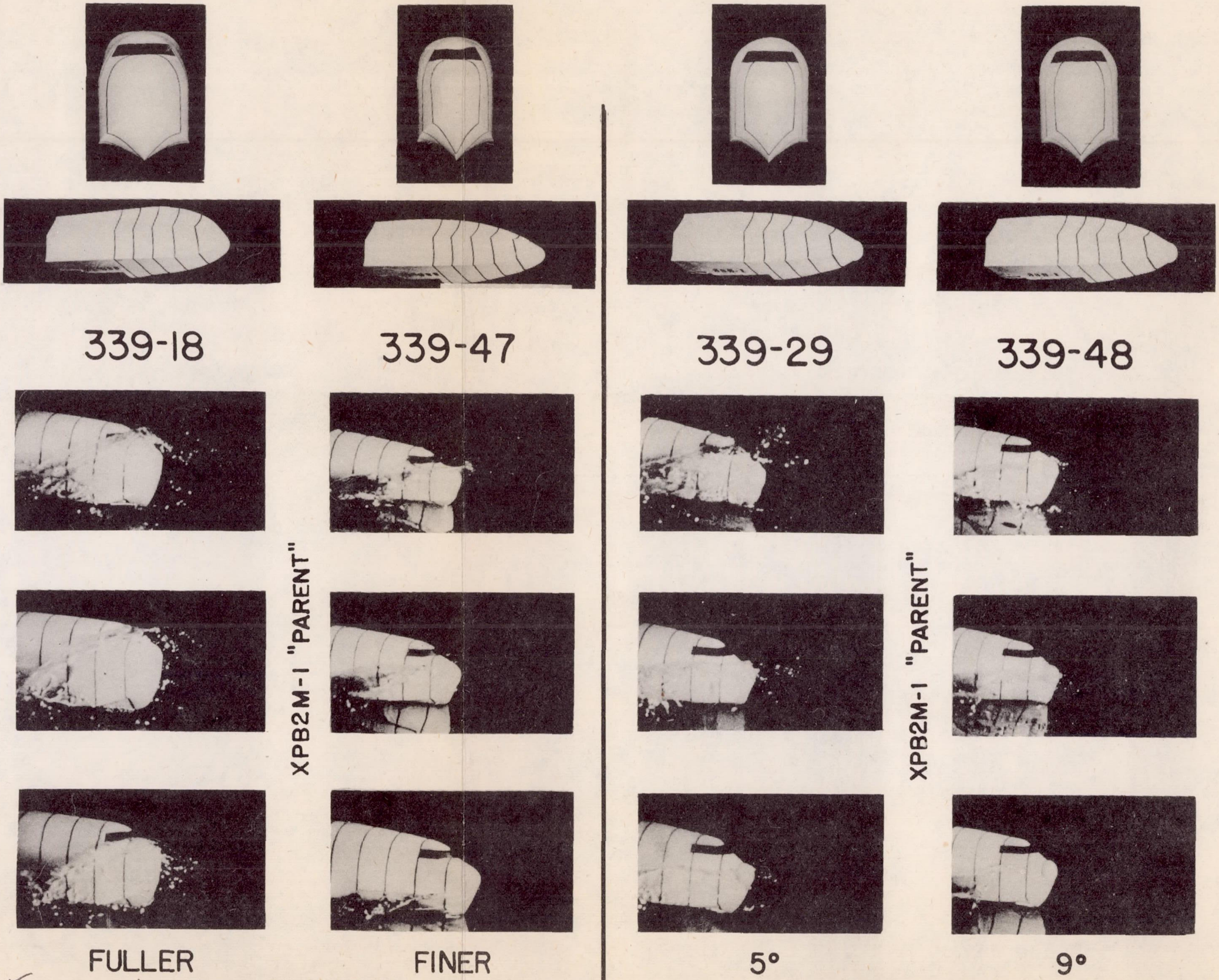
401-1



30°

HULL DEADRISE

FIG. 20



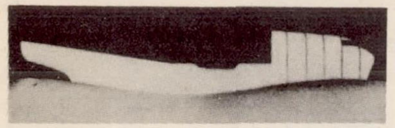
FOLD-OUT #2 BOW SECTIONS

AFTERBODY ANGLE

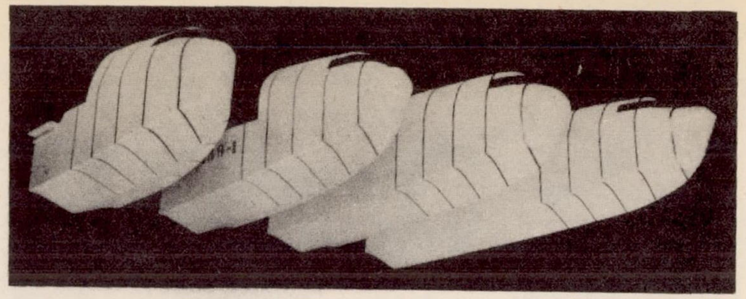
CHANGES OF LOAD AND LENGTH-BEAM RATIO

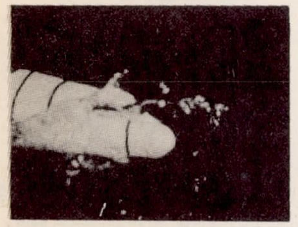
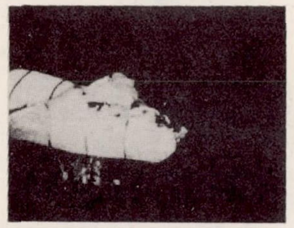
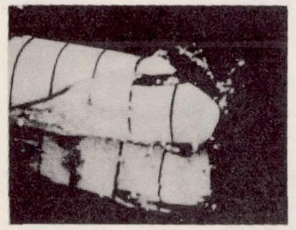
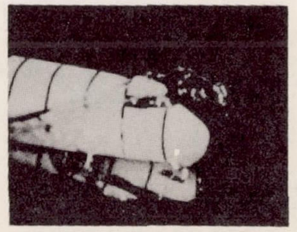
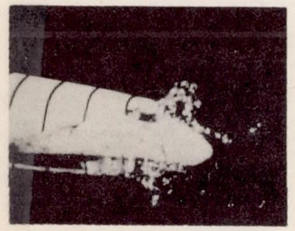
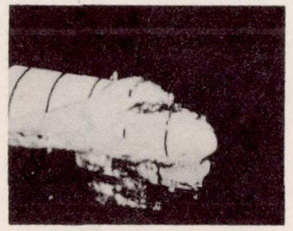
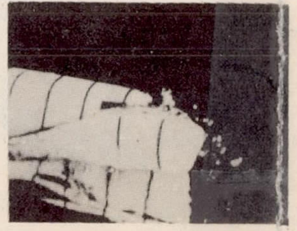
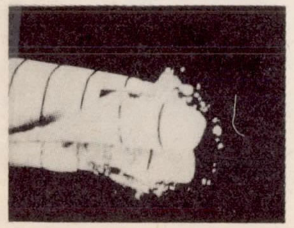
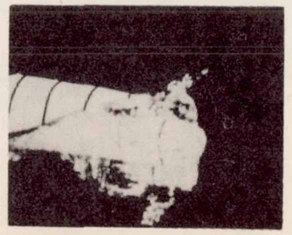
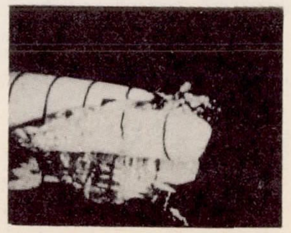
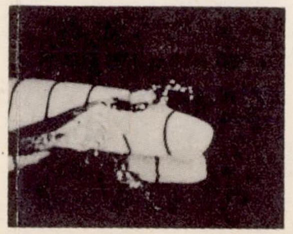
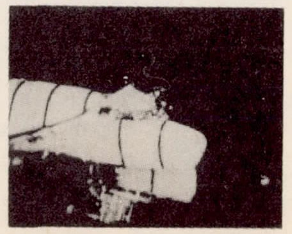
FIG. 21

H=0.3beam



L=6.0beam



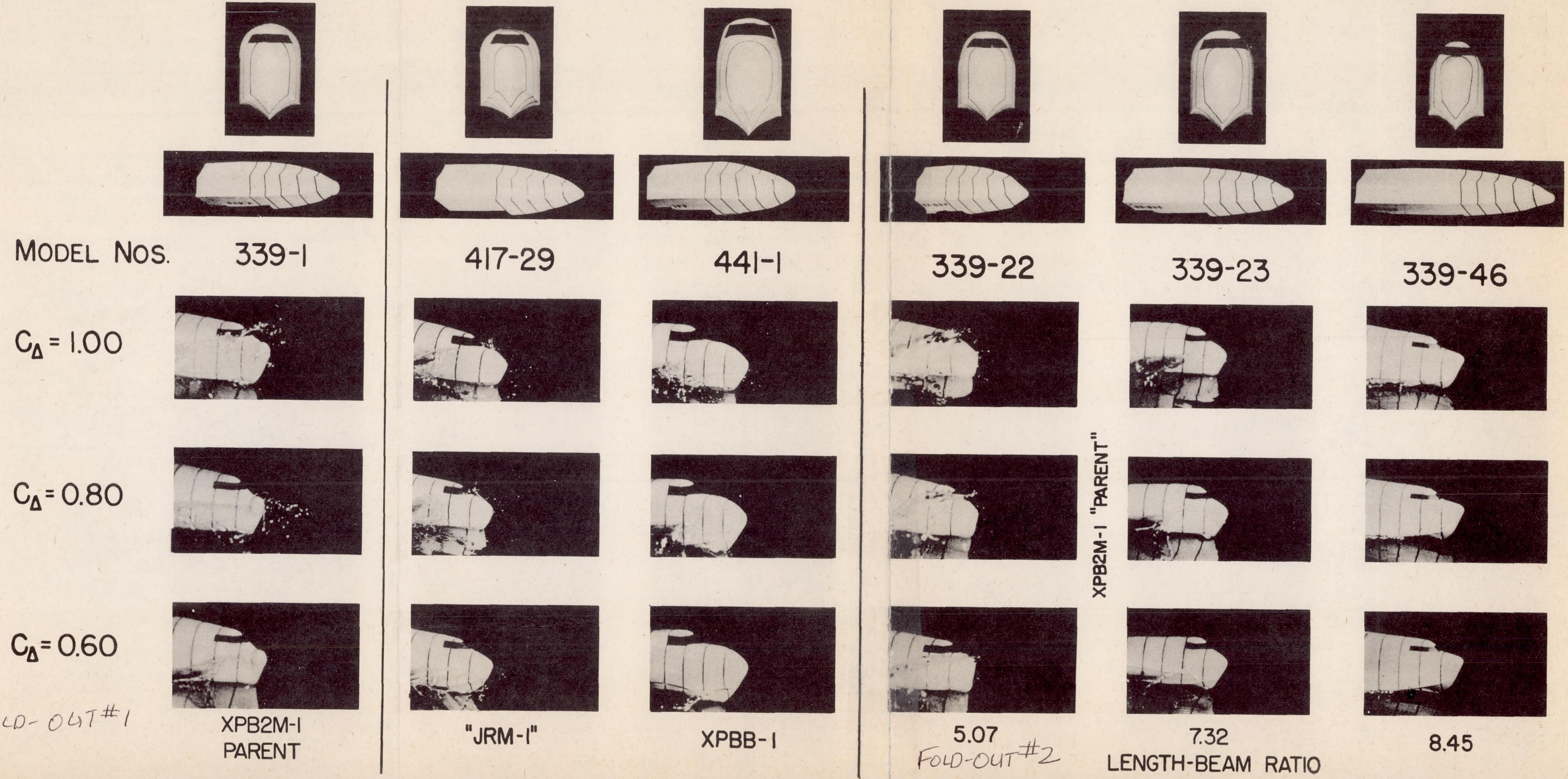
2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80
		MODEL TESTED BUT SANK							
NOT TESTED			NOT TESTED			MODEL TESTED BUT SANK			
									MODEL TESTED BUT SANK

FOLD-OUT #1

FOLD-OUT #2

FIGURE 20,

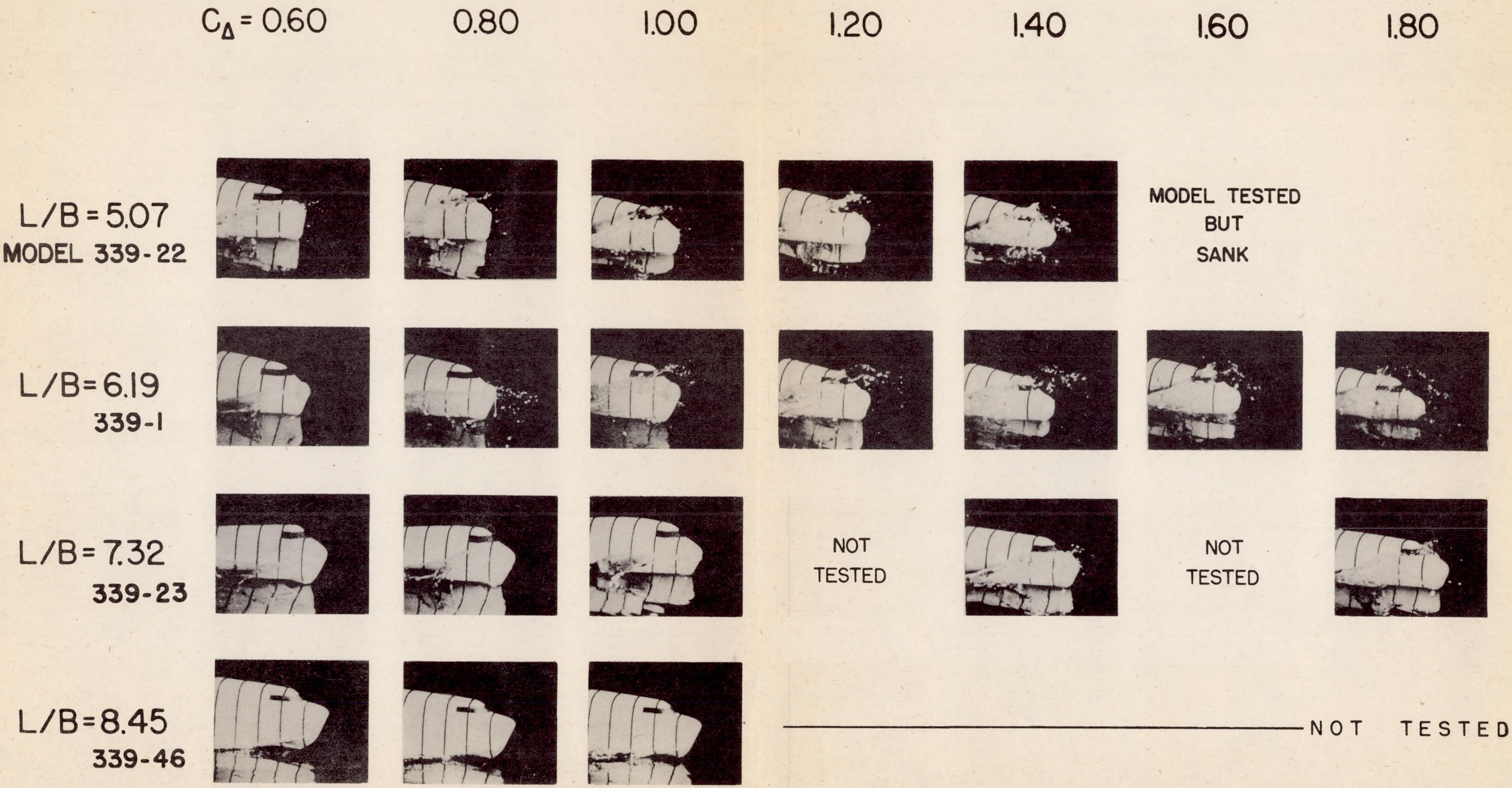
C_V=1.05



FOLD-OUT #1

FOLD-OUT #2

FIGURE 21. EFFECT OF $C_V = 1.05$



W-7 I